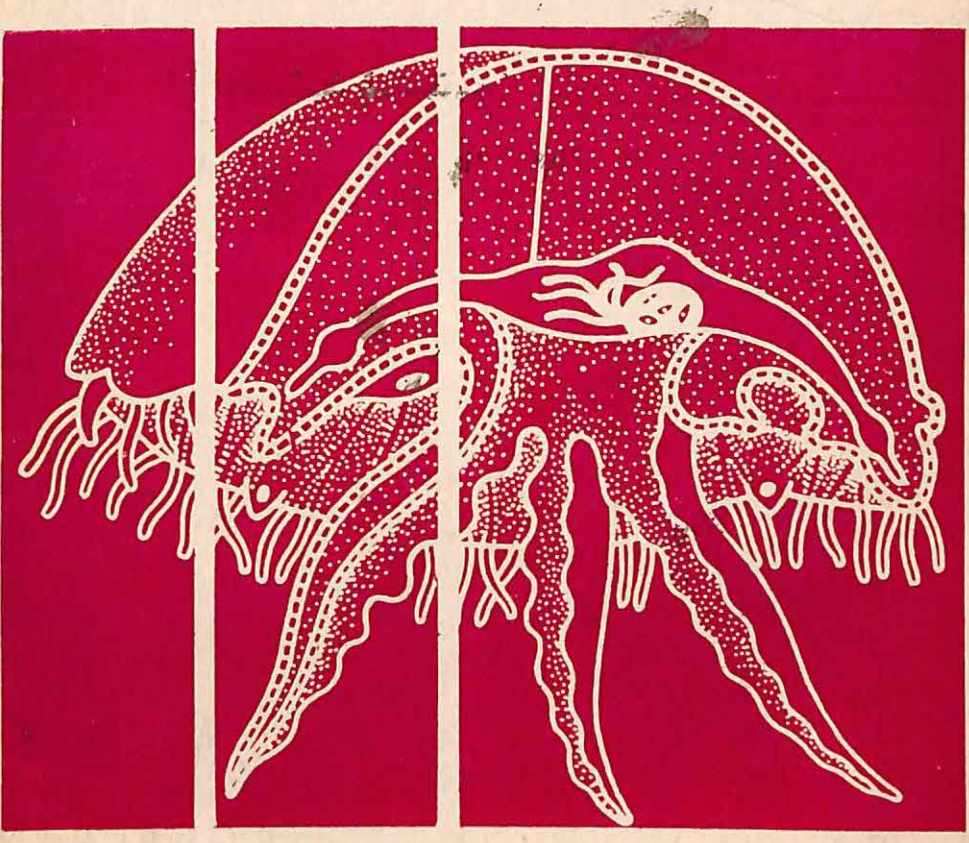
TEACH YOURSELF

ZOOLOGY



- PROTOZOA
- PORIFERA
- ORIGIN OF METAZOA
- COELENTERATA
- CTENOPHORA
- PLATYHELMINTHES
- ACNIDARIA
- NEMATHELMINTHES

BHARATI
BHAWAN
(P & D)

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PUBLISHER'S NOTE

TEACH YOURSELF Series have been brought out with a view to help students to prepare for University and various other examinations themselves independently.

The first book in the series includes Protozoa, Porifera, Origin of Metazoa, Coelenterata, Acnidaria (ctenophora), Platyhelminthes and Nemathelminthes.

The book begins with a QUESTION BANK comprising of various Universities as well as other typical & important questions. For guidance of the readers indication has been given against each question which refers to the chapter and article where the answer could be found. As for example : Ans. See 10.5 means that the answer will be found in Article 5 of Chapter 10.

The subject matters have been dealt with lucidly, exhaustively and with considerable depth and perceptible standard, eleminating unnecessary details so as to serve the purpose of MINI-TEXT-BOOK as also that of a question-answer book for preparing for different examinations.

We hope that the students & teachers will find the books of this series to be useful, beneficial and to their liking.

☐☐☐

CONTENTS

Chapters *Pages*

Question Bank .. i-x
1. Phylum-Protozoa .. 1-95
2. Phylum-Porifera .. 96-135
3. Origin of Metazoa .. 136-140
4. Phylum Coelenterata (Cnidaria) .. 141-205
5. Phylum Acnidaria (Ctenophora) .. 206-224
6. Phylum Platyhelminthes .. 225-263
7. Phylum Aschelminthes (Nemathelminthes) .. 264-284

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QUESTION BANK

1. Phylum—Protozoa

1. Enumerate the distinguishing features of phylum Protozoa and give an outline classification of the same with characters and examples of each class and order.

(**Ans** *See 1.2 and 1.3*)

2. Write short notes on—

(a) *Vorticella*, (b) *Polystomella*, (c) *Noctiluca*,
(d) *Opalina*, (e) *Giardia*, (f) *Balantidium*,
(g) *Ephelota*. (Ans. *See 1.4*)

3. Mention the characteristic features of phylum Protozoa and present an outline classification of the sub-phylum Plasmodroma up to orders giving their characters and examples.

(**Ans.** *See 1.2 and 1.3*)

4. Describe the structure and life-history of the protozoa parasite which causes amoebiasis. (P. U. 1980)

(**Ans.** *See 1.8, 1.10 and 1.11*)

5. Describe the morphology and life-cycle of the parasite which causes amoebic dysentry. (M. U. 1978; R. U. '79)

(**Ans.** *See 1.8, 1.10 and 1.11*)

6. Give an account of the structure, life-history and bionomics and economic importance of *Entamoeba histolytica*. (B. U. 1977, '79)

(**Ans.** *See 1.8, 1.9, 1.11 and 1.12*)

7. Describe the distribution, habit and habitat, structure and life-history of *Entamoeba histolytica*. In what way it is pathogenic to man ? (R. U. 1980)

(**Ans.** *See 1.7, 1.8, 1.10, 1.11 and 1.12*)

8. Describe the structure and life-history of *Entamoeba histolytica*. What disease it causes in human being ? (M. U. 1980, '82)

(**Ans.** *See 1.8. 1.11 and 1.12*)

9. Describe the structure and life-history of *Elphidium*.

(**Ans.** *See 1.14 and 1.15*)

10. Describe the structure of *Euglena*. Give reasons for its inclusion in the animal kingdom. (M. U. 1979)

(**Ans.** *See 1.17 and 1.22*)

11. Give an account of *Euglena* under the following heads : (a) structure, (b) locomotion, (c) nutrition.

(**Ans.** *See 1.17, 1.18 and 1.19*)

12. Give an account of the structure, nutrition and reproduction in *Euglena*. (Mithila U. 1976)
(**Ans.** *See 1.17, 1.19 and 1.21*)

13. Where is *Euglena* found ? Describe its mode of locomotion and nutrition. (**Ans.** *See 1.16, 1,18 and 1.19*)

14. Describe the structure, mode of reproduction and life-history of the *Trypanosoma* studied by you. (**Ans.** *See 1.27, 1.30 and 1.31*)

15. Give an account of the structure and life-history of *Trypanosoma gambiense*. Add a note on its pathogenecity.
(Mith. U. 1986; P. U. '79)
(**Ans.** *See 1.27, 1.31 and 1.35*)

16. Describe the structure and life-cycle of a *Trypanosoma*.
(Ran. U. 1976)
(**Ans.** *See 1.27, 1.30, 1.31, 1.32 and 1.33*)

17. What are the species of *Trypanosoma* pathogenic to man ? Describe the life-cycle and transmission of any one of them.
(**Ans.** *See 1.24, 1.30, 1.31, 1.32, 1.33, 1.34 and 1.35*)

18. What are haemoflagellates ? Describe the life-cycle and pathogenicity of *Trypanosoma gambiense*.
(**Ans.** *See 1.23, 1.30, 1.31, 1.32, 1.33. 1.34 and 1.35*)

19. Describe the structure and life-history of the protozoan parasite causing kala-azar. (**Ans.** *See 1.37 and 1.39*)

20. Describe the structure and life-cycle of *Leishmania donovani*.
(**Ans.** *See 1.37 and 1.39*)

21. Enumerate the different species of *Leishmania* pathogenic to man and describe the structure and life-cycle of the one causing kala-azar. (**Ans.** *See 1.36, 1.37 and 1.39*)

22. Give an account of the structure and life-history of *Monocystis*. (R. U. 1976)
(**Ans.** *See 1.41, 1.42 and 1.43*)

23. Give an account of reproduction in *Monocystis*. How does it infect earthworm ? (R. U. 1977, '80)
(**Ans.** *See 1.42 and 1.43*)

24. Describe the life-cycle of *Monocystis*. Explain its mode of infection. (M. U. 1981)
(**Ans.** *See 1.42 and 1.43*)

25. Describe the life-cycle of *Monocystis* and compare it with that of *Plasmodium*. (**Ans.** *See 1.42, 1.43 and 1.44*)

26. Describe the habits, habitat and structure of *Vorticella*. Mention the characters in which it resembles *Paramecium*.
(B. U. 1976, '86)
(**Ans.** *See 1.45, 1.46 and 1.49*)

27. Describe conjugation in *Vorticella* and state in what respect it differs from that of *Paramecium*. (**Ans.** *See 1.47 (ii) and 1.49*)

28. Describe the process of reproduction in *Vorticella*. Mention the features in which it shows an advance over *Paramecium*. (P. U. 1978) (**Ans.** *See 1.47 and 1.49*)

29. Give an account of the structure and biology of *Paramecium*. How would you obtain living Paramecia for demonstration ? (**Ans.** *See 1.51, 1.52, 1.53, 1.54, 1.55, 1.56, 1.57 and 1.59*)

OR Describe the structure of *Paramecium*. (**Ans.** *See 1.51*)

30. Give an account of nutrition, locomotor organelle and locomotion in *Paramecium*. (**Ans.** *See 1.52 and 1.53*)

31. Describe the process of reproduction in *Paramecium*. Compare the phenomenon of conjugation in this animal with that found in *Vorticella*. (**Ans.** *See 1.49, 1.56, 1.57 and 1.58*)

32. Give an account of locomotion in Protozoa. (P. U. 1982) (**Ans.** *See 1.60 and 1.61*)

33. Give an account of the locomotory organelles in Protozoa. Mention the current theories on the formation of Pseudopodia. (Mithila U. 1980) [**Ans.** *See 1.60 and 1.61 (A)*]

34. Give a detailed account of the locomotory apparatus and mode of locomotion in Protozoa. (P. U. 1986) (**Ans.** *See 1.60 and 1.61*)

35. Describe the organelles of locomotion in *Amoeba*, *Euglena*, *Paramecium* and *Monocystis* and discuss their importance in the classification of Protozoa. [**Ans.** *See 1.60 (A), 1.60 (B), 1.60 (C), 1.60 (D) and 1.3*]

36. Give an account of the various modes of locomotion in Protozoa. (**Ans.** *See 1.61*)

37. Write an essay on the modes of nutrition in Protozoa studied by you. (**Ans.** *See 1.62, 1.63, 1.64 and 1.65*)

38. Describe the various methods of nutrition found in Protozoa. (**Ans.** *See 1.62, 1.63, 1.64 and 1.65*)

39. Describe the various modes of reproduction found in the protozoa studied by you. (**Ans.** *See 1.66, 1.70, 1.71 and 1.72*)

40. Describe the role of nucleus in the reproduction of protozoa. (**Ans.** *See 1.67 and 1.68*)

41. Write an essay on 'Sexual Reproduction in Protozoa'. (Mithila U. 1976) (**Ans.** *See 1.72 and 1.73*)

42. Write an essay on 'Parasitism in Protozoa'.
(Ans. *See 1.75—1.80*)

43. Write an essay on 'Osmoregulation in Protozoa'.
(Ans. *See 1.81*)

2. Phylum—Porifera

44. Classify Porifera up to orders giving salient features and examples of each group. Justify the inclusion of porifera in the sub-kingdom 'Parazoa'. (Bhag. U. 1979)
(Ans. *See 2.1. 2.2, 2.3 and 2.35*)

45. Classify phylum porifera up to orders with their salient features and examples.
(M. U. 1979; Mith. U. '76; R. U. '80; B. U. '80)
(Ans. *See 2.1, 2.2 and 2.3*)

46. Describe the general organisation of sponges. (M. U. 1982)
(Ans *See 2.4, 2.5, 2.6—2.11*)

47. Describe the skeleton of sponges (B. U. 1983) and state its importance in the classification of the phylum (M. U. 1983)
(Ans. *See 2.4, 2.5, 2.6 and 2.7*)

48. Describe the structure and functions of the various types of cells found in the body-wall of sponges. (B. U. 1977, '81)
(Ans. *See 2.8*)

49. Trace the evolution of canal system in the phylum porifera.
[Bhag. U. 1982 (R)]
(Ans. *See 2.9 and 2.10*)

50. Describe the different kinds of canal system found in sponges.
(R. U. 1981; P. U. '83 R; Mith. U. '81)
(Ans. *See 2.9 & 2.10*)

51. Describe the reproduction in sponges. (Ans. *See 2.11 & 2.12*)

52. Describe the different kinds of larvae found in sponges.
(Ans. *See 2.12*)

53. Describe the habit and habitat, external features and nutrition in *Sycon*. (Ans. *See 2.14, 2.15 & 2.17*)

54. Give the cellular organization of *Sycon* and point out its special features. (P. U. 1983)
(Ans. *See 2.16*)

55. Describe the structures and functions of different kinds of cells found in the body-wall of *Sycon*.
(M. U. 1986; Bhag. U. '80, '82)
(Ans. *See 2.16*)

56. Give an account of canal system in *Sycon* and add a note on the economic importance of sponges. (M. U. 1980, '82; P. U. '83)
(Ans. *See 2.18 & 2.24*)

57. Describe the main histological elements found in *Sycon* and indicate their functions. (B. U. 1979)
(**Ans**. *See 2.16*)

58. Give a detailed account of the process of reproduction and development in *Sycon*. (M. U. 1976; Mith. U. '78)
(**Ans**. *See 2.19*, *2.20*, *2.21*, *2.22 & 2.23*)

59. Describe the life-cycle in *Sycon*. (Bhag. U. 1978)
(**Ans**. *See 2.20*, *2.21*, *2.22 & 2.23*)

60. Write short notes on :

(a) Spicules (M. U. 1982) (**Ans**. *See 2.4*))
(b) Scleroblast (B. U. 1979) (**Ans**. *See 2.8*)
(c) Anphiblastula (B. U. 1981, '82; B. U. '83; P. U. '83) (**Ans**. *See 2.23*)
(d) Choanocytes (B. U. 1983; P. U. 1983) (**Ans**. *See 2.8*)
(e) Gemmule (R. U. 1980) (**Ans**. *See 2.11*)
(f) Bath sponge (Bhag. U. 1978) (**Ans**. *See 2.33*)
(g) *Hyalonema* (**Ans**. *See 2.27*)
(h) *Chalina* (**Ans**. *See 2.30*)
(i) *Euplectella* (**Ans**. *See 2.26*)
(j) *Cliona* (**Ans**. *See 2.29*)
(k) *Oscarella* (**Ans**. *See 2.28*)
(l) *Spongilla* (**Ans**. *See 2.31*)
(m) Neptune's goblet (**Ans**. *See 2.32*)
(n) Affinitics of sponges (**Ans**. *See 2.34*)

61. Discuss on the origin of sponges. (**Ans**. *See 2.37*)

3. Origin of Metazoa

62. Give an account of the origin of Metazoa.
(**Ans**. *See 3.1*, *3.2*, *3.3 and 3.4*)

4. Phylum—Coelenterata (Cnidaria)

63. Classify coelenterata (cnidaria) up to orders giving characters and examples. (Mith. U. 1977; M. U. '77, '82)
(**Ans**. *See 4.1*, *4.2 and 4.3*)

64. Describe the structure of polyps and medusa of *Obelia*. Add a note on the development of medusa.
(M. U. 1976, '78, '80; Bhag. U. '76; P. U. '78)
(**Ans**. *See 4.4*, *4.5*, *4.6*, *4.7*, *4.8 and 4.9*)

65. Describe the different types of zooids in *Obelia* and give an account of polymorphism exhibited by them. (R. U. 1976; P. U. '77)
(**Ans**. *See 4.4*, *4.5*, *4.6*, *4.8 and 4.10*)

66. Describe the life-history of *Obelia* and discuss the significance of medusa. Does the life-history of *Obelia* exhibit true alternation of generation ? (P. U. 1978, '80, '81; Bhag. U. '76; R. U. '80)
(**Ans**. *See 4.12*, *4.13*, *4.14 and 4.15*)

67. In what respects a typical polyp differs from a medusa ? (P. U. 1983)
(**Ans.** *See 4.16*)

68. Are polyp and medusa homologous structures ? How can one be derived from the other ? (M. U. 1978)
(**Ans.** *See 4.17*)

69. Describe the structure of *Aurelia.* (Mith. Univ. 1978; Ran. Univ. '79, '81; Mag. Univ. '81)
(**Ans.** *See 4.20, 4.21, 4.22, 4.23, 4.24, 4.26 and 4.27*)

70. Give an illustrated account of the life-history of *Aurelia.* Does it exhibit alternation of generation ?
(Mag. Univ. 1977, '81; Pat. Univ. '78)
(**Ans.** *See 4.28, 4.29, 4.30 and 4.31*)

71. Give an account of the life-history of *Aurelia.* In what respects does it differ from that of *Obelia* ?
(Ans. *See 4.28, 4.29, 4.30 and 4.32*)

72. Describe the development and life-history of *Aurelia.*
(M. U. 1979; P. U. '83)
(**Ans.** *See 4.28. 4.29 and 4.30*)

73. Give full page diagram of the life-history of *Aurelia.*
(**Ans.** *See 4.30 only figure no. 4.20*)

74. Compare the life-history of *Aurelia* with that of *Obelia.*
(P. U. 1977)
(**Ans.** *See 4.32*)

75. Describe the structural differences between *Obelia* medusa and *Aurelia.* (Mith. U. 1976; B. U. '77; R. U. '77)
(**Ans** *See 4.33*)

76. Give an account of coral and coral formation.
(P. U. 1976, '77, '78, '81, '82, '83; M. U. 82)
(**Ans.** *See 4.34, 4.35, 4.36, 4.37 and 4.38*)

77. What is a coral reef ? Give an account of different types of reefs. (P. U. 1977, '78)
(**Ans.** *See 4.39*)

78. Describe the different theories which have been propounded by various authorities to explain the great vertical thickness of coral reefs and mention briefly the significance of reefs.
(**Ans.** *See 4.40 and 4.41*)

79. Describe the structure of a sea-anemone.
(**Ans.** *See 4.44, 4.45, 4.46, 4.47 and 4.48*)

Or Describe the general organisation of *Metridium.*
(M. U. 1978; P. U. '83)
(**Ans.** *See 4.44, 4.45, 4.46, 4.47 and 4.48*)

80. Give an account of mesenteries of sea-anemone. (P. U. 1978)
(**Ans.** *See 4.46 and 4.47*)

81. Give an account of movements and musculature of sea-anemone. (**Ans.** *See 4.48*)

82. Give an account on the histology of the body-wall of sea-anemone and add a note on its digestive system, nervous system and sense-organs. (Ans. *See 4.49, 4.50, 4.51 and 4.52*)

83. Describe the reproductive system and life-history of sea-anemone. (Ans. *See 4.53*)

84. Give an account of mesentery formation in a sea-anemone. (Ans. *See 4.54*)

85. Compare Sea-anemone with a hydroid polyp. (Ans. *See 4.55*)

86. Compare Sea-anemone with a scyphozoan polyp, Scyphistoma. (Ans. *See 4.56*)

5. Phylum—Acnidaria (Ctenophora)

87. Give an account of characters and classification of Ctenophora and also point out the resemblances and differences between Ctenophora and Cnidaria. (Ans. *See 5.2, 5.3, 5.4, 5.5 and 5.6*)

88. Describe the structure, anatomy and development of *Hormiphora*. (Mag. Univ. 1976, '79; Pat. Univ. 1977, '78, '83) (Ans. *See 5.8, 5.9, 5.10, 5.11, 5.12, 5.16 and 5.19*)

89. Describe the development of *Hormiphora*. (Ans. *See 5.19*)

90. Discuss the affinities of Ctenophora. (P. U. 1980, '82, '83; M. U. 1979) (Ans. *See 5.20*)

6. Phylum—Platyhelminthes

91. Give the chief characters of phylum platyhelminthes. Classify up to order with suitable example. (Ans. *See 6.1 and 6.2*)

92. Describe the structure and life-history of any turbellaria included in your syllabus. (B. U. 1979) (Ans. *See 6.3, 6.6, 6.7, 6.9 to 6.14*)

93. Give an account of the life-history of *Fasciola hepatica*. (Mith. U. 1986; Bhag. U. '82; P. U. '83; B. U. '86) (Ans. *See 6.17-6.30, pp. 220-228 all in short*)

94. Give an account of the structure of *Fasciola hepatica*. (M. U. 1979) (Ans. *See 6.17-6.24*)

95. Describe the reproductive system of *Fasciola hepatica* and point out the parasitic adaptations found in its structures. (Ans. *See 6.24 and 6.31*)

96. Describe the structure and life-cycle of any trematode parasitic in blood of man. (Ans. *See 6.33 to 6.36*)

97. Give an illustrated account of the structure and life-history of *Taenia solium*. (B. U. 1979; Bhag. U. '78; M. U. '82) (Ans. *See 6.41-6.48 all in short*)

98. Describe the structure of a ripe proglottid of *Taenia solium*. (M. U. 1980, '82; P. U. '83)

(Describe as you see in figure 6.30 with reference to text nos. 6.45, 6.46 & 6.47)

99. Describe the parasitic adaptations in Platyhelminthes with reference to the forms studied by you.
(B. U. 1980; M. U. '82; Bhag. U. '84)
(**Ans.** *See 6.31 and 6.49*)

100. Give an account of the parasitic adaptations of *Taenia solium*.
(P. U. 1982)
(**Ans.** *See 6.49; pp. 262-263*)

101. Give a comparative account of the body-wall of *Planaria*, *Fasciola*, *Taenia* and *Ascaris*. (M. U. 1983)
(**Ans**. *See 6.7, 6.18, 6.42 and 7.6 with corresponding figures on pp. 231, 240, 257 and 268*)

102. Write short notes on :
(i) *Schistosoma* (B. U. 1977, '81, '83; M. U. '82)
(**Ans.** *See 6.33-6.38 all in short*)
(ii) Flame cell (B. U. 1977)
(**Ans.** *See 6.10*)
(iii) Bladder worm (M. U. 1980; R. U. '80)
(**Ans.** *See it in 6.48*)
(iv) Cercaria (M. U. 1980)
(**Ans.** *See 6.29*)

7. Phylum—Nemathelminthes

103. Describe the reproductive organs and life-cycle of *Ascaris*.
(Bhag. U. 1980, '83)
(**Ans.** *See 7.12 and 7.13*)

104. Name any three nematodes which are harmful to man and describe the life-history of the nematode studied by you.
(M. U. 1976)
(**Ans.** *See part of 7.2 parasitic nematodes of man in Nematode, classification, and 7.13*)

105. Describe the structure and life-history of the parasite which causes filaria in man. (M. U. 1983)
(**Ans**. *See 7.17, 7.18 & 7.19*)

106. Give a brief account of the structure and life-history of *Wuchereria bancrofti*. (M. U. 1979; P. U. '83; Mith. U. '81)
(**Ans.** *See 7.17, 7.18 and 7.19*)

107. Give labelled diagrams of the following :
(i) T. S. of male *Ascaris* (B. U. 1977; M. U. '81)
(**Ans.** *See fig. 7.8*)
(ii) T. S. of female *Ascaris* (Mith. U. 1979)
(**Ans.** *See fig. 7.10*)
(iii) Microfilaria (B. U. 1980; Bhag. U. '83; R. U. '80)
(**Ans.** *See 7.18 and fig. 7.15*)

□□□

1. PHYLUM PROTOZOA

1.1. The Phylum Protozoa includes a variety of the simplest animals, many of whom bear marked similarity to the plants. Protozoans are single celled microscopic organisms found almost everywhere in water, soil and air. Many of them live as parasites in man and domestic animals causing diseases. Some protozoans living in water help to purify it.

1.2. Distinguishing Features of Phylum Protozoa

(i) Protozoans are simple minute animals possessing simple differentiations or **organelles** within the one-celled body to perform various functions.

(ii) They are **unicellular** as the body is structurally similar to a cell; but their bodies cannot be distinguished or divided into cells, and so they are called **acellular.**

(iii) Body usually with a single nucleus, sometimes many nuclei and in one group two types of nuclei are present.

(iv) Locomotion with the help of locomotor organelles—**pseudopodium, flagellum** or **cilium.** In some forms without locomotor organelle superficial **microtubules** help in movement.

(v) Nutrition is obtained by various means :

(a) **Holozoic**—engulfing other organisms,

(b) **Holophytic or autotrophic**—photosynthesizing food,

(c) **Saprozoic**—absorbing dead organic matter,

(d) **Saprophytic** or **parasitic**—absorbing liquid food from the environment.

(vi) Some are provided with tests or shells, many secrete protective cysts or spores to tide over unfavourable environment.

(vii) Exchange of gases and removal of metabolic wastes are carried out through the general body surface.

(viii) Asexual reproduction takes place by **binary** and **multiple fission**. Some multiply by **budding** and **plasmotomy.**

(ix) Sexual reproduction occurs either by **conjugation** or **syngamy.**

1.3. Classification of Phylum Protozoa

There is disagreement among Protozoologists on the ways of classifying protozoa. Modern workers like **Barnes** (1980) and **Kazloff** (1972) tend to believe that this group includes more than one unicellular phyla. **Barnes** (1980) raises the four major groups viz., **Mastigophora, Sarcodina, Sporozoa** and **Ciliophora** to the rank of independent phylum. The conventional classification of Protozoa based largely on the nature of the locomotor organelle and the pattern of reproduction is followed here.

The phylum is divided into three sub-phyla :

1. **Sarcomastigophora**
2. **Sporozoa**
3. **Ciliophora**

Sub-Phylum 1. Sarcomastigophora :

Characters—(i) Locomotory organelle either pseudopodia or flagella, (ii) Nucleus of one kind, (iii) Sexual reproduction by syngamy i.e., complete fusion of gametes, nucleus with nucleus and cytoplasm with cytoplasm.

This sub-phylum is divided into two classes—

Class I Sarcodina (*Sarcodes* = **fleshy**, referring to pseudopodia formation).

Characters—(i) Pseudopodia act as locomotor organelle, (ii) No definite cytostome, ingestion of food assisted by pseudopodia, (iii) Majority are free-living forms, (iv) Body in some cases protected by internal or external shell.

Sub-class Rhizopoda—(*Rhizos* = **root**, *podos* = **foot**)—Pseudopodia without internal filaments.

Order 1. Amoebina (Lobosa)—(i) Pseudopodia short lobe-like called lobopodia, (ii) Body form changing.

Ex. *Amoeba*, *Pelomyxa* (a soil amoeba), *Entamoeba*, *Hartmanella* (feeds on bacteria in foul water).

Order 2. Testacea—(i) Pseudopodia branched and filiform called-filopodia, (ii) Body covered with siliceous or calcareous shell consisting of a single chamber, (iii) Majority of forms found in fresh water.

Ex. *Arcella*, *Euglypha*, *Difflugia*.

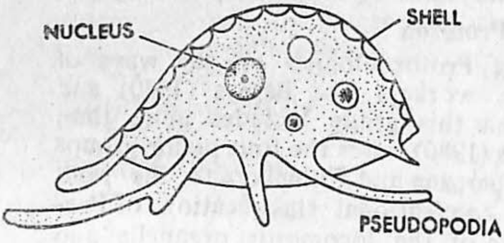

Fig. 1.1. *Arcella*

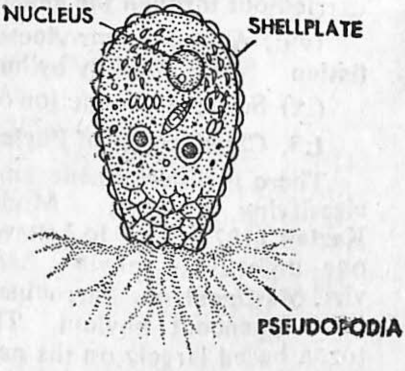

Fig. 1.2. *Euglypha*

Order 3. Foraminifera—(i) Pseudopodia slender, branched and anastomosing i.e., branches reunite to form reticulum, (ii) Ectoplasm secretes a many-chambered calcareous shell, (iii) Sexual reproduction by syngamy, asexual reproduction by multiple fission or **Schizogony,** (iv) Many forms exhibit dimorphism and alternation of sexual and asexual generations.

Ex. *Elphidium* (=*Polystomella*), *Globigerina.*

Fossil foraminifera serve as indicators of oil-bearing strata during prospecting for oil.

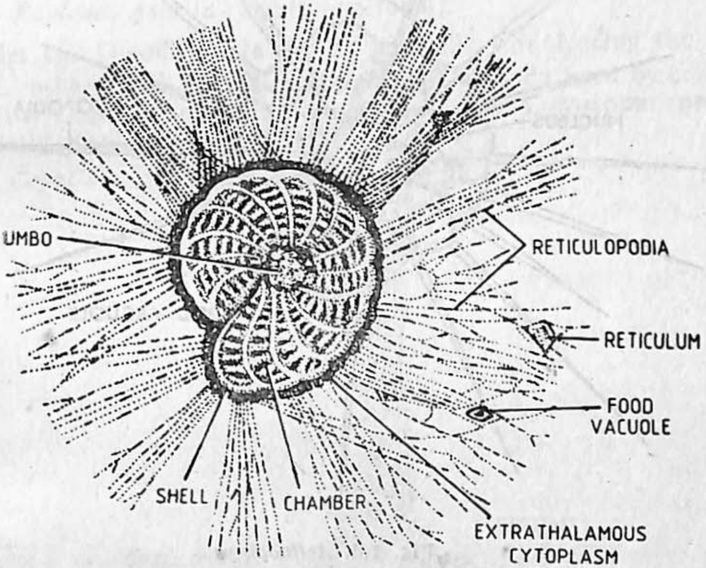

Fig. 1.3. *Elphidium=Polystomella*

Order 4. Mycetozoa—(i) Fully grown body is a multinucleate sheet of protoplasm, (ii) Saprozoic on decaying matter, (iii) Reproduction by resistant cellulose coated spores.

Ex. *Ceratomyxia, Badhamia.*

Sub-class Actinopoda (*Actinos*=spine, referring to the central filament)—Radially disposed filamentous pseudopodia stiffened with a central or axial filament.

Order 5. Radiolaria—(i) Body divided into internal and external parts separated by an internal perforated skeletal **central capsule,** (ii) Ectoplasm highly vacuolated, (iii) Marine pelagic forms.

Ex. *Actinomma, Collozoum, Aulacantha.*

Order 6. Heliozoa—(i) No central capsule, (ii) Mostly fresh-water forms.

Ex. *Actinophrys, Actinosphaerium, Clathrulina.*

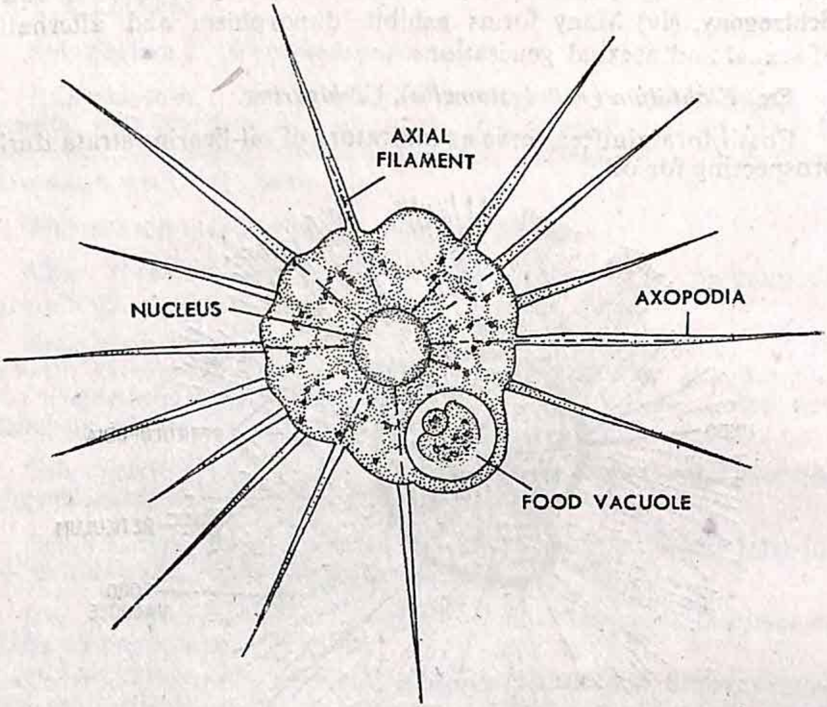

Fig. 1.4. *Actinophrys*

Class II. Mastigophora (*Mastix* = whip, meaning flagellum) or Flagellata.

(i) Locomotory organelle is flagellum, rarely pseudopodia may also be present, (ii) Shape usually fixed due to a thin outer covering of pellicle, (iii) Ingestion of food at the cytostome aided by flagellum, (iv) Plane of binary fission is longitudinal.

Sub-class Phytomastigina—Flagellates possessing chloroplast. Nutrition holophytic. Reserve food starch, paramylum or oil. Many forms are included among unicellular algae.

Order 7. Chrysomonadina—(i) **Astomatous** flagellates with 1-2 yellow or brown chloroplast, (ii) Pellicle thin, 1-2 flagella.

Ex. *Chrysamoeba, Chromulina, Ochromonas.*

Order 8. Cryptomonadina—(i) Cytostome present, (ii) Pellicle is firm, 1-2 usually unequal flagella, (iii) 1-2 yellowish brown chloroplast.

Ex. *Chilomonas* (saprophytic), *Cryptomonas.*

Order 9. Phytomonadina— (i) Cytostome absent, (ii) Pellicle reinforced by cellulose covering, (iii) Chloroplast is green or brown, (iv) Flagella 1-4.

Ex. *Chlamydomonas*, *Pandorina*, *Volvox* (Colonial).

Order 10. Chloromonadina—(i) Two flagella, rudimentary cytostome, (ii) Many chloroplasts but no stigma (photosensitive spot).

Ex. *Coelomonas*.

Order 11. Euglenoidea—(i) Two very unequal flagella originating from the gullet, (ii) Chloroplasts green, stigma present, (iii) Reserve food is paramylum.

Ex. *Euglena*, *Astasia* (Colourless form).

Order 12. Dinoflagellata—(i) Two flagella, one skirting the body and the other trailing behind, (ii) Shape of body fixed by cellulose test, (iii) Chloroplast many or none, (iv) Cytostome present, (v) Mostly planktonic.

Ex. *Ceratium*, *Noctiluca* (bioluminescent).

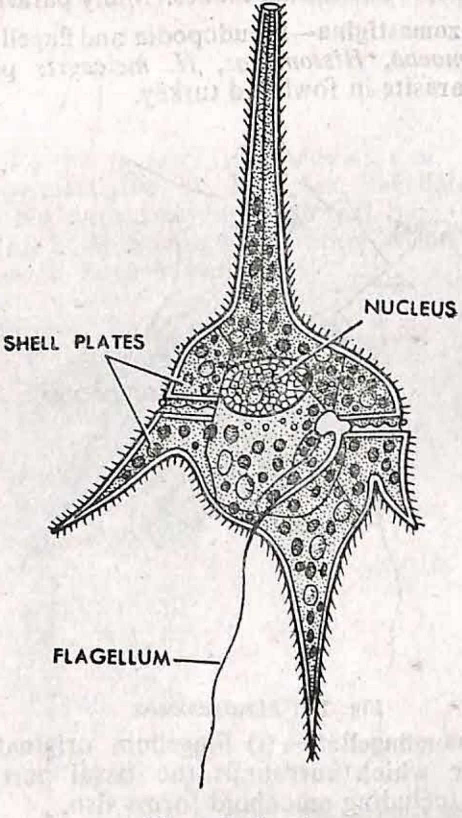

Fig. 1.5. *Ceratium*

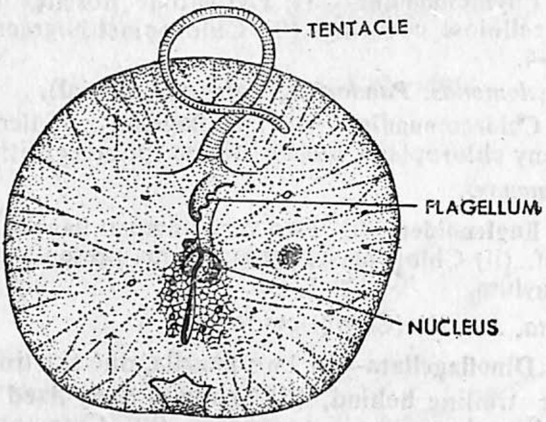

Fig. 1.6. *Noctiluca*

Sub-class Zoomastingina—Non-chlorophyllous flagellates with holozoic or saprozoic nutritional modes. Many parasitic forms.

Order 13. Rhizomastigina—Pseudopodia and flagella both present. **Ex.** *Mastigamoeba, Histomonas, H. meleagris* pathogenic i.e., disease causing parasite in fowl and turkey.

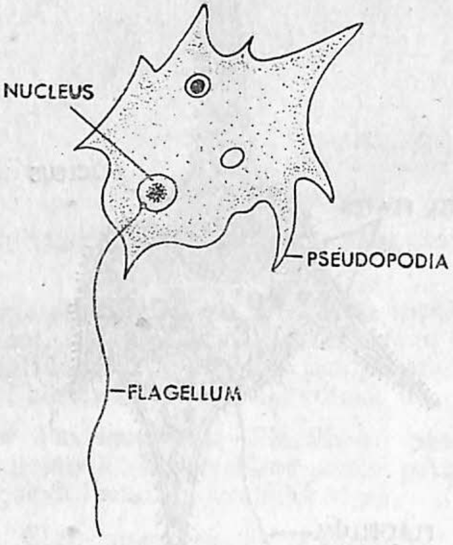

Fig. 1.7. *Mastigamoeba*

Order 14. Choanoflagellata—(i) Flagellum originates from the centre of a collar which surrounds the basal part of flagellum, (ii) Often colonial including amoeboid forms also.

Ex. *Proterospongia.*

Order 15. Protomonadina. (i) 1-2 flagella, (ii) Astomatous, often parasitic in blood, lymph, etc. called haemoflagellates.

Ex. *Trypanosoma, Leishmania.*

Order 16. Polymastigina—(i) Heterogenous group. 3.8 or more flagella, (ii) Cytostome when present is rudimentary, (iii) Many are intestinal parasites.

Ex. *Giardia, Trichomonas, Chilomastix.*

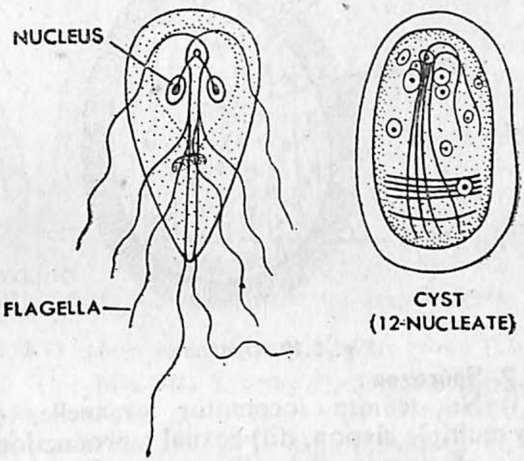

Fig. 1.8. *Giardia* : Trophozoite and Cyst

Order 17. Hypermastigina—(i) Complex flagellates with numerous flagella, (ii) No cytostome, ingestion with help of pseudopodia like formations, (iii) Symbiotic in wood eating insects like termites.

Ex. *Trichonympha, Lophomonas.*

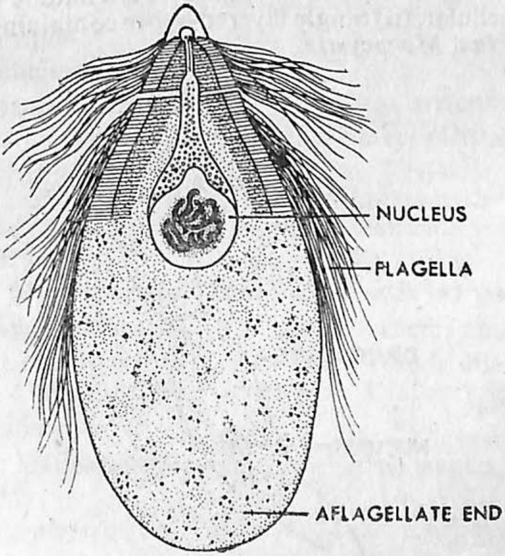

Fig. 1.9. *Trichonympha*

Class III Opalinata (= sub-class **Protociliata**).

Order 18. Opalinida—Numerous cilia in oblique rows, (ii) No cytostome, saprophytic, (iii) Nuclei 2 or many, of one kind, (iv) No conjugation.

Ex. *Opalina.*

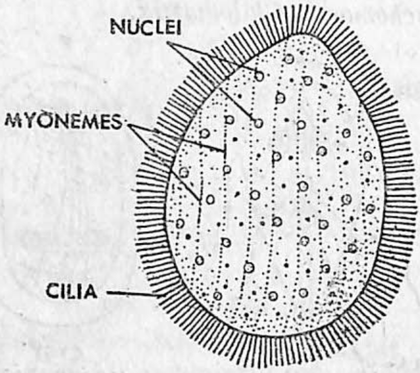

Fig. 1.10. *Opalina*

Sub-phylum 2. Sporozoa :

Character (i) No definite locomotor organelle, (ii) Asexual reproduction by multiple fission, (iii) Sexual reproduction associated with formation of spores, (iv) All are parasitic.

Class IV Telosporidia :

Characters : (i) Trophozoite uninucleate, (ii) Spores simple devoid of polar capsules and filaments, (iii) Spores are formed after sexual reproduction.

Order 19. Gregarinida—(i) Trophozoite is a minute vermicule, mobile and extracellular, (ii) Single layered-spore containing 8 sporozoites.

Ex. *Gregarina, Monocystis.*

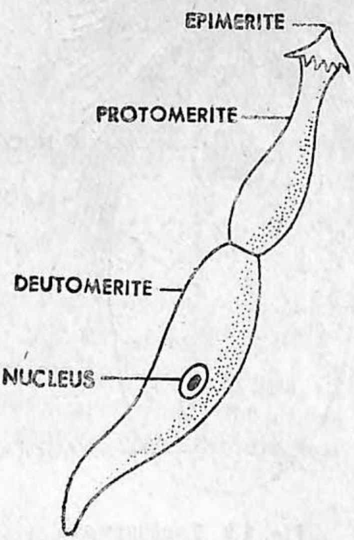

Fig. 1.11. *Gregarina*

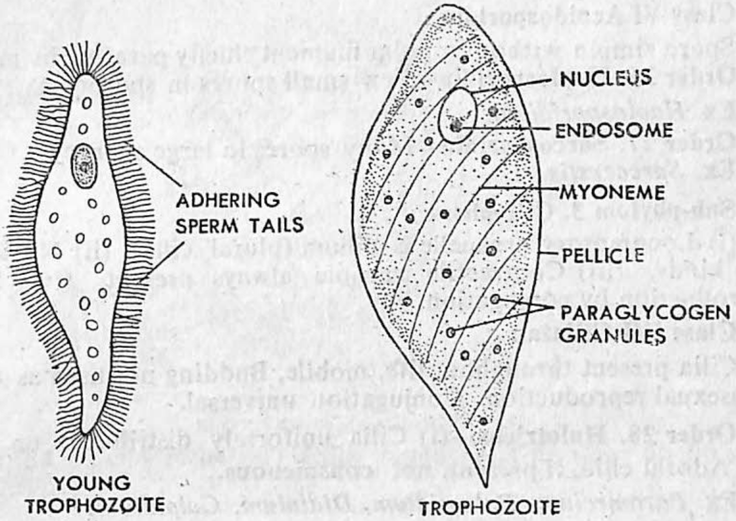

Fig. 1.12. *Monocystis* : Young and fully grown Trophozoite

Order 20. Coccidia—(i) Trophozoite small intracellular nonmotile, (ii) Spores with more than one layer of protective coat, (iii) Asexual multiple fission (—**schizogony**) is followed by spore formation (—**sporogony**) consequent to syngamy.

Ex. *Eimeria, Isospora.*

Order 21. Haemosporidia—(i) Trophozoite is intracellular and amoeboid, (ii) Zygote motile, (iii) Sporozoites not protected, (iv) Schizogony in vertebrates host alternates with sporogony in blood-sucking arthropods, (v) Gametes dissimilar.

Ex. *Plasmodium.*

Class V Cnidosporidia :

(i) Trophozoite multinucleate, (ii) Spores are complex structure with polar capsule containing polar filament (1 to 4 in number) to anchor to host cell.

Order 22. Myxosporidia—(i) Spore large with two halves of protective case (—bivalve, (ii) 1-4 polar filaments.

Ex. *Myxidium.*

Order 23. Microsporidia—Spore small with 1-2 polar filaments.

Ex. *Nosema* (pathogenic in silk worm and honey bee); *N. bombycis* causes pebrine in silkworm. *N. apis* affects honey bee.

Order 24. Actinomyxidia—Spore with 3 valves and 3 filaments.

Ex. *Triactinomyxon.*

Order 25. Helicosporidia—Spore barrel-shaped with a single coiled filament.

Ex. *Helicosporidium.*

Class VI Acnidosporidia :

Spore simple without a polar filament chiefly parasitic in muscles.

Order 26. Haplosporidia—Few small spores in sporocyst.

Ex. *Haplosporidium.*

Order 27. Sarcosporidia—Many spores in large sporocyst.

Ex. *Sarcocystis.*

Sub-phylum 3. Ciliophora :

(i) Locomotory organelle is cilium (plural cilia), (ii) Nucleus of two kinds, (iii) Contractile vacuole always present, (iv) Sexual reproduction by conjugation.

Class VII Ciliata :

Cilia present throughout life, mobile, Budding not used as means of asexual reproduction. Conjugation universal.

Order 28. Holotricha—(i) Cilia uniformly distributed on body, (ii) Adoral cilia, if present, not conspicuous.

Ex. *Paramecium, Balantidium, Didinium, Colpidium.*

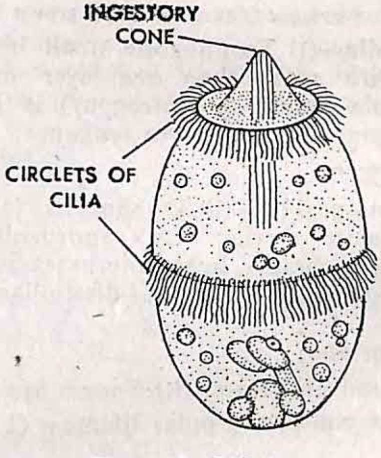

Fig. 1.13. *Didinium*

Order 29. Peritricha—(i) Ciliation reduced to a couple of whorls at oral end of body, (ii) Stalked, often colonial forms.

Ex. *Vorticella, Zoothamnium, Epistylis.*

Order 30. Hypotricha—(i) Body flattened dorsoventrally, (ii) Cilia fused to form small membranelle or **cirrus** restricted to ventral surface.

Ex. *Stylonychia, Euplotes.*

Order 31. Spirotricha—Ciliation reduced to spirally disposed adoral units and undulating or endoral membranelle.

Ex. *Stentor, Spirostomum, Nyctotherus.*

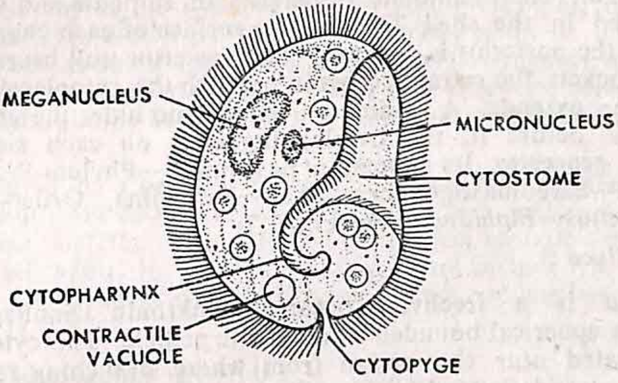

Fig. 1.14. *Nyctotherus*

Order 32. Chonotricha—(i) Cilia absent in adult stage on body surface; (ii) Stalked.

Ex. *Spirochona.*

Class VIII Suctoria :

(i) Cilia present in young stage only, (ii) Stalked animals, (iii) Astomatous, tentacles help in sucking food organisms, (iv) Asexual reproduction by budding.

Ex. *Acineta, Ephelota, Podophrya.*

1.4. Short Notes on Some Protozoa

(a) *Vorticella*—See 1.45 and 1.46,

(b) *Polystomella(=Elphidium)* :

Elphidium is a **dimorphic** marine **multilocular** foraminifera. The cytoplasm secretes a multichamber perforate calcareous shell through which large number of delicate filamentous branching and anastomosing pseudopodia emerge out. The chambers are added to the shell as the protozoan increases in size. The first chamber to be secreted is small and thick-walled in the **microspheric** form. In the other type called **megalospheric** the initial chamber is large and thin-walled. The microspheric is multinucleate schizont reproduces asexually, the megalospheric individual is a gamont and reproduces by syngamy. The two generations—schizogonic and syngamic alternate with one another. The **reticulopodia** trap and paralyse living food organism, which is digested in food vacuoles formed at the reticula outside the shell in the **extrathalamous cytoplasm.** The foraminifers have a very long geological history and fossils of this group are used as **index of oil-bearing strata** by geologists.

Successive chambers are **equitant** on the preceding ones and arranged in a **flat logarithmic spiral.** The $CaCO_3$ crystals forming the shell are deposited on an organic base covering the cytoplasm of the animal. Small amount of magnesium sulphate and silica is also included in the shell. The anterior surface of each chamber is convex and the posterior is concave. The posterior wall bears series of small pockets the **retral process** into which the cytoplasm filling the chamber extends. A chamber overlaps and hides the chamber immediately before it, the overlapping ends on each side are called **alar processes**. Its systematic position is—Phylum-Protozoa, Sub-phylum—Sarcomastigophora, Class—Sarcodina, Order—Foraminifera, Genus—*Elphidium*. (See Fig. 1.3)

(c) *Noctiluca* :

Noctiluca is a freeliving oceanic planktonic Dinoflagellata. The body is spherical bounded by a definite pellicle. The cytoplasm is concentrated near the centre from where branching reticular cytoplasmic strands extend to the pellicle. The body is gelatinous about 1 mm in diameter. A **cytopharynx** is located in a notch-like depression leading to the cytostome. A delicate flagellum and a cross striated ribbon like tentacle emerge from the cytopharynx. The cytoplasm is vacuolated and contains plenty of oil droplets. *Noctiluca* is phosphorescent. It reproduces by longitudinal binary fission as well as by sungamy of uniflagellate gametes. The gametes are produced on a dome-shaped area on the surface formed at the onset of reproductive activity after the single nucleus has divided repeatedly to form a large number of nuclei. Each nucleus occupies the centre of a uniflagellate gamete. Ingestion of food is assisted by the flagellum. Lashing of tentacle helps in locomotion. (See Fig. 1.6)

Its classification is :

Phylum—Protozoa
Subphylum—Sarcomastigophora
Class—Mastigophora
Sub-class—Phytomastigina
Order—Dinoflagellata
Genus—*Noctiluca*

(d) *Opalina* :

Opalina is an **endocommenal** protozoan found in the rectum of frogs and toads. The body is flattened and oval in shape about 1 mm in length. The pellicle appears folded under the Electron microscope, and bears numerous cilia of equal length. Cilia are arranged in longitudinal oblique grooves. Cytostome, contractile vacuole and cytopyge are absent. The nuclei are of one kind. The animal is **saprozoic**. It reproduces asexually by diagonal **plasmotomy** (binary fission not preceded by nuclear division).

When the hosts are about to breed small opalinids with only a few nuclei arise from the repeated division of the adult individual. They sorround themselves with a cyst wall. The cysts are expelled with the faeces, are swallowed by young tadpoles, and reach the hindgut. They either grow to a multinuclear adult or undergo divisions to form uninucleate dissimilar gametes. Syngamy among micro and megagametes produces **cystozygotes.** They are often passed out and swallowed by another frog in which they develop into the adult form.

Opalina is a peculiar protozoan. It has cilia as locomotor organelle, but lacks duality in nucleus, does not undergo conjugation and has lost the cytostome and contractile vacuole due to endocommensal habit. In view of these it is not included in class Ciliata but an independent class for its sole occupancy has been established. (See Fig. 1.10)

Its systematic position is :
Phylum—Protozoa
Sub-phylum—Sarcomastigophora
Class—Opalinata
Order—Opalinida
Genus—*Opalina*

(e) *Giardia* :

The most common species *G. intestinalis* is a binucleate pyriform flagellate found in small intestine of man with two sets of four flagella. An annular fibril surrounds a concave ventral depression serving as a sort of sucker for attachment of the parasite to the intestinal muccosa. The parasite causes giardial dysentery or giardiasis in man. The flagella form a system of intracellular fibrils before they leave the body. Two pairs of flagella leave the body at the sides, one pair ventrally and the remaining pair from the posterior end. The body is about 12 μm long and 8·5 μm broad on the average.

Multiplication occurs by longitudinal binary fission. Intermittently the parasite encysts. The cysts are passed with faeces and remain viable for about 10 days. Infection to fresh hosts is caused by intake of water and food contaminated with cyst of *G. intestinalis*. (See Fig. 1.8).

Species of *Giardia* are very numerous and live as parasites in vertebrates ranging from fish to man.

Its systematic position is :
Phylum—Protozoa
Sub-phylum—Sarcomastigophora
Class—Mastigophora
Sub-class—*Zoomastigma*
Order—Polymastigima
Genus—*Giardia.*

(f) *Balantidium* :

Balantidium is an **endocommensal** in large intestine of many vertebrates. *B-coli* is found in man, monkeys and pigs. This species is oval or pear shaped 50-80 μm long and 35-60 μm in breadth. The body is covered with fine cilia in longitudinal oblique rows. At the anterior end is a funnel shaped depression called vestibule lined with specially long adoral cilia running spirally backward into the cytostome. The meganucleus is dumb-bell shaped and large. while the micronucleus is small and inconspicuous. They have a pair of contractile vacuoles a cytopyge at the posterior ends and many food vacuoles. *B. coli* multiplies by transverse binary fission. It feeds holozoically on cell fragments. bacteria and blood cells.

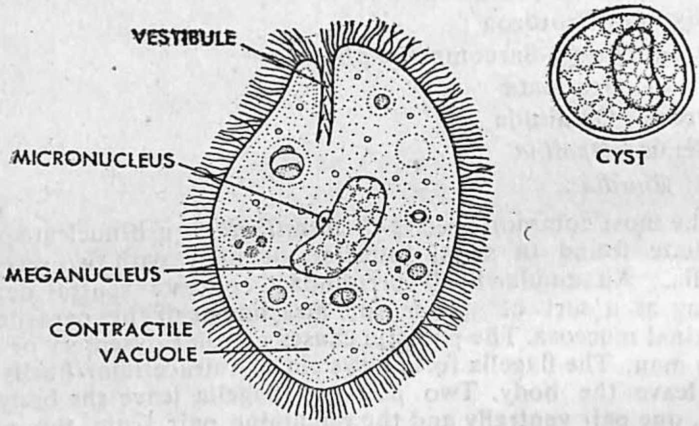

Fig. 1.15. *Balantidium* : Trophozoite and Cyst

Conjugation in *B. coli* has been reported. Cysts are passed with faeces. Man gets the infection when cysts reach his alimentary canal. The parasite often causes ulceration of the large intestine causing balantidiosis or balantidial dysentery.

Its systematic position is :

Phylum—Protozoa

Sub-phylum—Ciliophora

Class—Ciliata

Order—Spirotricha

Genus—*Balantidium.*

(g) *Ephelota* :

Ephelota is a large suctorian protozoa attached to algae, hydroids etc. by a stalk. The stalk bears the body which is broad apically and narrow near the basal end from where the stalk originates. At the free apical and many **pointed tipped** trapping **tentacles** are given off together with **capitate suctorial tentacles**. The meganucleus is large and branched but the micronucleus is small.

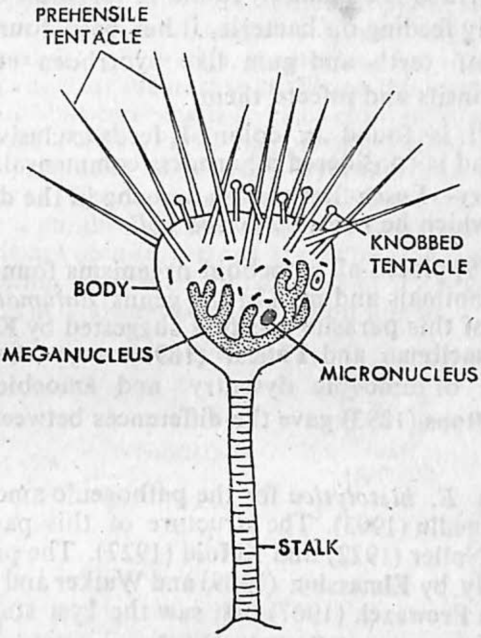

Fig. 1.16. *Ephelota*

Ephelota multiplies by binary fission, but more commonly it forms 4-12 **extrnal buds** at its apical surface which separate, develop cilia and swim away. Each ciliated young later loses cilia, develops a stalk and attaches to the organisms on which it is commonly found. During conjugation there is complete fusion of the two conjugants and fertilisation is unilateral.

Food organisms are trapped by the tapering tentacles. These prehensile tentacles to which the food sticks pass on the prey to the knobed suctorial tentacles. The prey is then sucked into the developing hollow of the tentacle and enclosed in a food vacuole at the base of the tentacle. The capitate tentacles have anchoring organelles called **haptocysts** at their tips.

Its systematic position is :

Phylum—Protozoa, Sub-phylum—Ciliophora, Class—Suctoria, Order—Suctorida, Genus—*Ephelota*.

ENTAMOEBA HISTOLYTICA

1.5. Three species of **Entamoeba** are found in man.

(i) *E. histolytica* is a pathogenic parasite found in the colon and a variety of other organs and tissues causing amoebic dysentery; amoebic abscess of liver, spleen, kidney, diaphragm etc. which is collectively called amoebiasis.

(ii) *E. gingivalis* is commonly found in tarter on teeth and in gum. Though largely feeding on bacteria, it has been found to aggravate the diseases of teeth and gum like pyorrhoea etc. It sometimes reaches the tonsils and infects them.

(iii) *E. coli* is found in colon. It feeds exclusively on bacteria, food debris and is considered a harmless commensal.

1.6. History—**Losch** first saw an amoeba in the dysentric stool of man in 1875 which he named *Amoeba coli.*

Leidy (1879) placed all amoeboid organisms found in the alimentary canal of animals and man in the genus *Entamaeba*. The pathogenic nature of this parasite was first suggested by **Koch** and **Gaffky** in 1886. **Councilman** and **Lafleur** (1891) were the first to study the pathology of amoebic dysentry and amoebic liver abscess. **Quincke** and **Roos** (1893) gave the differences between *E. histolytica* and *E. coli*.

The name *E. histolytica* for the pathogenic amoeba in man was given by **Schauddin** (1903). The structure of this parasite has been studied by **Noller** (1922) and **Kofoid** (1927). The precyst stage was studied initially by **Elmassion** (1909) and **Walker** and **Sellards** (1913). **Hartmann** and **Prowazek** (1907) first saw the cyst stage. **Broeck** and **Drobohlav** (1927) successfully cultured the parasite in the laboratory and paved the way for the study by **Dobell** (1919-28) on the binary fission and mitosis, by **Cleveland** and **Sanders** (1939) on excystment. The ultrastructure of *Entamobea* has been studied by **Miller** and co-workers (1961) and **Fletcher** and co-workers (1962).

1.7. Distribution—*E. histolytica* is almost world-wide in distribution (i.e., it is cosmopolitan) but more common in tropical and semi-tropical countries where sanitation and personal hygiene is poor.

1.8. Structure—*E. histolytica* is found in three stages in man i. e. the **trophozoite** or actively feeding form, the **precyst** and the infective resistant stage—the **cyst**. The species appears in man in two racial forms.

(i) A small race or **minuta** form which always lives in the lumen of colon. In is not a tissue invading form, feeding largely on tissue debris, food remains and bacteria. It is largely harmless.

(ii) a large race or **magna** form which invades the tissue feeding on enzymatically dissolved host cells, erythrocytes and tissue fragments. It is highly pathogenic.

Trophozoite—This stage is rarely found in human stool but can be cultured in the laboratory. It measures from 7 to 50 µm in diameter ; the small race ranging in size from 7·12 µm and the large race from 15 to 50 µm. A freshly expelled vegetative form is very active, moving in flowing locomotion with the help of a prominent lobe-like pseudopodium. The cytoplasm is clearly distinguished into an outer, clear, hyaline and refractile ectoplasm surrounding a granular greenish endoplasm. A single nucleus is slightly eccentrically placed. In stained individuals, the nucleus has a characteristic appearance. The nuclear membrane is thin to the inside of which is arranged a thin but prominent layer of chromatin granules. In the centre of the nucleus is a small karyosome. Between the karyosome and the peripheral chromatin layer faint radially disposed linin fibres are seen. The nucleus measures 3-7 µm in diameter. In the endoplasm a number of food vacuoles mostly containing RBC and cell fragments are seen in various stages of digestion. Trophozoite is found in intestinal ulcers and abscess of the organs. Trophozoite of minuta form is always found in colon lumen.

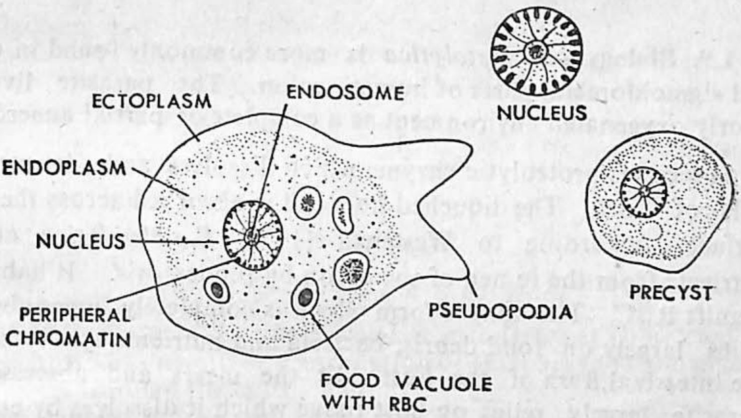

Fig. 1.17. *Entamoeba histolytica.* Trophozoite and Precyst stages. The nucleus of trophozoite is shown magnified at the top

Precyst—The precyst is smaller than trophozoite. It is colourless, devoid of food vacuoles, relatively sluggish with little pseudopodial formation. The nuclear membrane is thicker and the karyosome larger than that of the trophozoite. It measures 12-15 µm in diameter in the magna form, in the small race it is about half the size. Precysts of both races are always found in the lumen of colon and is incapable of tissue invasion. It sometimes passes out with the stool. Vacuoles with stored **glycogen** begin to appear at this stage. Deeply staining bodies which are bar-like with rounded ends are often seen in precyst. These are **chromatoid bars.**

Cyst—The precyst secretes a thin (0·5 µm) cyst wall of scleroprotein and becomes cyst which is 12-20 µm in diameter in the large race and is half as small in the small race. A freshly-formed cyst is uninucleate but as it matures it becomes quadrinucleate by two successive divisions of the nucleus. The mass of glycogen and chromatoid bars at first increases but as the cyst matures appears to have been largely utilised.

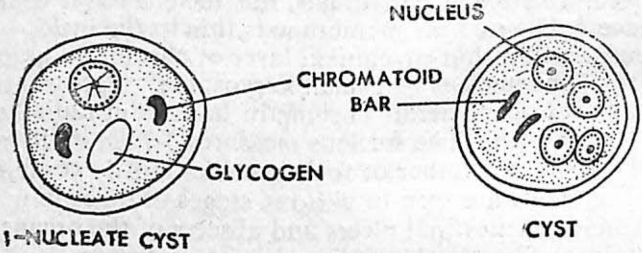

Fig. 1.18. Immature and mature Cyst of *E. histolytica*

1.9. Biology—*E. histolytica* is more commonly found in caecal and sigmoidorectal parts of human colon. The parasite lives in poorly oxygenated environment as a complete or partial anaerobe.

It secretes proteolytic enzyme which dissolves and disintegrates cells of host. The liquefied host cell is absorbed across the body surface. According to **Westphall** (1976) *E. histolytica* absorbs nutrients from the lumen of the colon by pinocytosis. It habitually engulfs RBC. The minuta form which is completely lumen-dwelling relies largely on food debris, bacteria and nutrients synthesized by the intestinal flora of the host. In the ulcers and abscesses the parasite largely relies on host tissue which it dissolves by enzymes it secretes.

1.10. Reproduction—*E. histolytica* multiples by binary fission in which nuclear division largely mitotic precedes cytoplasmic cleavage. The steps in binary fission are:

(i) Nucleus enlarges in size and assumes spindle shape.

(ii) Peripheral chromatin migrate towards the centre of nucleus.

(iii) Chromosomes appear, 6 pairs according to **Kofoid** and **Swezy** (1925) and arrange on the centre of the spindle formed between the opposite poles of the stretched nuclear membrane.

(iv) Nucleus constricts at the middle forming two nuclei.

(v) Cytoplasm cleaves into two and thus two daughter **E. histolytica** are produced.

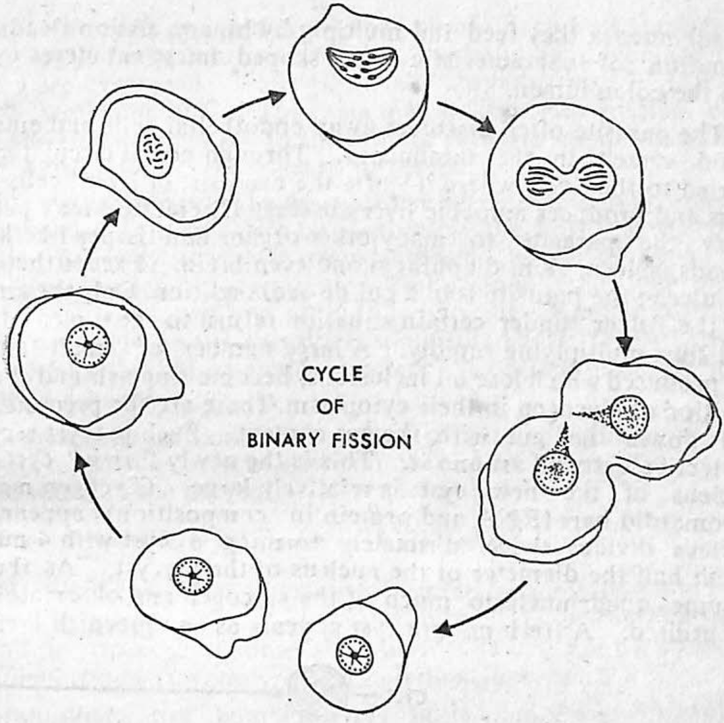

Fig. 1.19. Binary fission in *E. histolytica*

1.11. Life Cycle—The life cycle of ***E. histolytica*** is completed in a single host i. e., man. The transmission of this parasite from man to man occurs through the cysts. The cyst which is the only stage infective to man is passed out with stool. It gains entry into another host through contaminated food and drink. Once inside the human gut, the cyst wall is ruptured in the small intestine and a metacystic amoeba with four nuclei is liberated in the lumen of the ileum. This is called excystment. The nuclei divide once forming 8 smaller nuclei which is followed by cytoplasmic cleavage resulting in eight small *E. histolytica* which gradually pass into colon and develop into fully grown trophozoite If the parasite belongs to the small race, it stays in colon lumen. The trophozoite of large race gradually erodes the mucosal layer, dissolving it and relying on the liquefied cells and tissues for its nourishment. The parasite pushes deeper as it dissolves the cells, ultimately reaching the submucosa. **In**

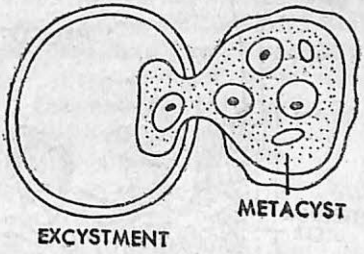

Fig 1.20. Excystment in *E. histolytica*

the submucosa they feed and multiply by binary fission leading to formation of characteristic flask-shaped **intestinal ulcers** opening into the colon lumen.

The parasite often dissolves away endothelial cells and enters the blood vessels in the submucosa. Through portal circulation it is carried to the liver, where it starts the necrosis, of liver cells multiplies and produces amoebic liver abscess. Circulation may passively carry the parasite to many other organs and tissues like kidney, gonads, spleen, skin, diaphragm and even brain. Except the intestinal ulcers; the parasite is in a cul-de-sac condition. Only the amoebae in the ulcer under certain situation return to the lumen of colon and start multiplying rapidly. A large number of small amoebae are produced which lose all inclusions, become sluggish and show deposition of glycogen in their cytoplasm. These are the precysts. They roll down the gut with the gut content. Each precyst secretes a protective cystwall around it. This is the newly formed cyst. The nucleus of the new cyst is relatively large. Glycogen mass and chromatoid bars (RNA and protein in composition) appear. The nucleus divides twice, ultimately forming a cyst with 4 nuclei of about half the diameter of the nucleus of the precyst. As the cyst becomes quadrinucleate much of the glycogen and chromatoid bars are utilised. A fresh mature cyst appears as a greenish refractile

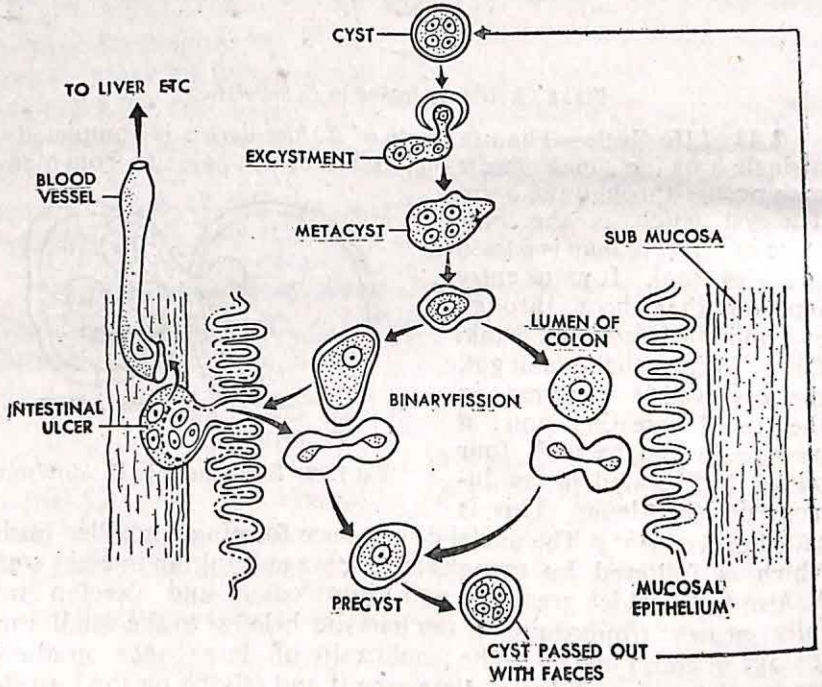

Fig. 1.21. Diagrammatic life cycle of *E. histolytica.* The tissue invading large race is on the left and the lumen dwelling small race on the right side of the diagram

sphere. The cysts are voided with the stool of the host and transmission to a fresh host occurs, when food and drink contaminated by cysts are consumed. The cyst usually survives outside the host for 2·5 weeks at 20°C. The cysts may be dispersed by flies, cockroach and other animals. In the minuta race the mode of precyst and cyst formation is the same as in magna form.

1.12. Pathogenicity—The magna form secretes histolytic enzymes in its immediate vicinity thereby dissolving the host tissue. They penetrate (literally eat their way) through the mucosal layer into submucosa causing characteristic flask-shaped intestinal ulcers. Bacteria enter the ulcers and cause inflammation. Abscess is formed in other organs when the parasite is spread to those areas through blood circulation. In amoebic dysentery the patient passes mucous and blood with stool.

Improvement in sanitation, better personal hygiene, effective disposal of sewage and protection of food and water from contamination help in the prevention of amoebiasis.

ELPHIDIUM (=POLYSTOMELLA)

1.13. *Elphidium* is a member of order Foraminifera and is represented by a large number of species inhabiting warm temperate seas and in tropical shallow sea-water. The best known species is *Elphidium crispum* (formerly called *Polystomella crispa*).

Foraminifers are comparatively large amoeboid organisms capable of secreting and living inside a calcareous shell in the intertidal zone of the sea as well as shallow depths of the sea. Majoriy of foraminifers live inside complicated multi-chambered shell with a pseudochitinous base on which $CaCO_3$ crystals are carefully laid out. Some foraminifera are pelagic like *Globigerina* and *Hastigerina* When dead the calcareous shell with dead cytoplasm constantly fall to the bottom of the sea. Over the years there has been considerable accumulation of globigerinidae shells in the bottom of the temperate seas. The chemical reaction between the calcareous substance of the shell and acidic products of decomposition causing a continuous oozing of gas bubbles from the accumulated shells in the ocean bed. Such oceanic bottom is said to be formed of Globigerina ooze. Another shelled protozoan order—the Radiolaria similarly constitutes radiolaria ooze in certain areas of oceanic bed.

Foraminifers are a very ancient group of protozoa. Due to the possession of a shell fossil remains of these animals are well known. Some fossil foraminifers are used as indicators of oil-bearing strata in borings to drill oil well.

1.14. Structure of Elphidium

E. crispum creeps about on sea-weed and sand in the littoral zone of the sea down to 300 fathoms. The body is lodged inside

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a calcareous shell of many chambers (polythalamous). The shell is about 1 mm in diameter and divided into a number of chambers by septa. The successive chambers intercommunicate by openings on the septa. The surface of the shell also bears pores. So, the shell of Elphidium is perforate. In the young animal a small spherical initial chamber or **proloculum** is laid down. As the animal feeds and grows successive chambers are added one by one. The succeeding chambers are laid down serially in the locus of a planar logarithmic spiral with the largest or the most recent chambers lying above those of the earlier whorls of the spiral. The newer chambers are larger and partially overlap the older or earlier chambers, so that the older chambers get hidden from view. The overlapping process of a chamber on either side of the chamber of earlier whorl is called **alar process**. Alar processes are equitant upon the parts of the shell they cover. Along the posterior and concave margin of each chamber are pocket-like depressions in each chamber called **retral process**. Between retral processes in each chamber are minute pores through which cytoplasm comes out of the shell and encases the shell in a thin layer of **extra-thalamus cytoplasm**. The centre of the shell is called **umbo** and the earliest formed chambers are concealed by secondary calcareous deposits. All chambers are ridged with a continuous keel at the shell periphery. Inside the shell the animal's body is in the form of a single continuous protoplasmic mass which as it grows continually adds chambers of ever-increasing dimension until the size limit is reached. Near the centre of the series of chambers is a single large nucleus or a number of scattered nuclei depending on whether the individual is **megalospheric** or **microspheric**.

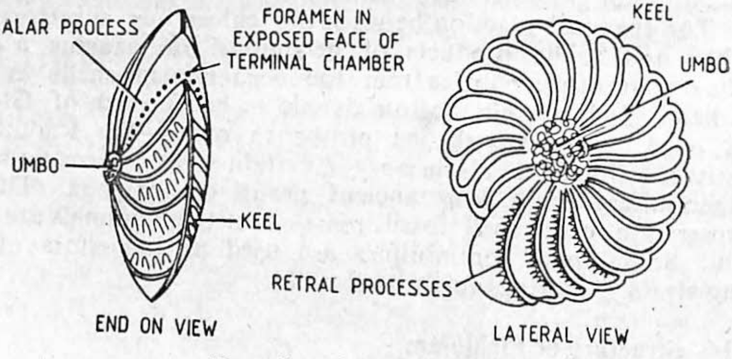


Fig. 1.22. Shell of *Elphidium*

The cytoplasm is not differentiated into ectoplasm or endoplasm. As the animal is found in sea, in a hyperosmotic medium, a contractile vacuole is not found. Cytoplasmic inclusions include brownish granules or **stercomata**, symbiontic algae etc. A large number of fine, pointed, slender, branching and anastomosing pseudopodia radiate out from the **extra-thalamus** cytoplasm. The rhizopodia wave about in water. They can be withdrawn with lightning rapidity and may be shot out with equal ease and quickness. The pseudopodia immobilise living algae, pennate diatoms, chlorophytes, bacteria etc., which are later taken into food vacuoles at the reticula where two or more pseudopodia anastomose. The pseudopodia also help the animal to crawl on the substratum and weeds. The food is usually digested outside the shell and the assimilated material is sent in the interior through the inward streaming movements in the pseudopodia.

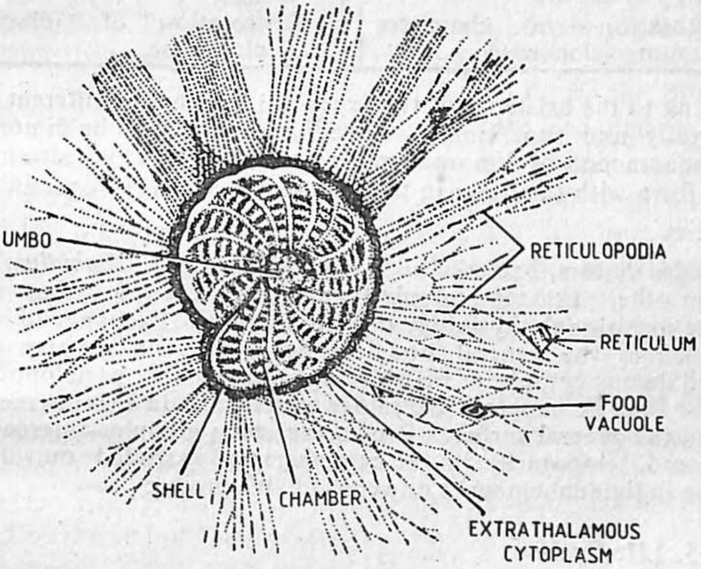


Fig. 1.23. *Elphidium=Polystomella*

The genus *Elphidium* exists in two distinct structural forms or **morphe**. One set of individuals has a large initial chamber or proloculum, possesses a single nucleus and normally reproduces sexually by producing gametes which undergo syngamy. These individuals are called **megalospheric**. The other set of individuals begins their life with a small proloculum, possesses many small nuclei and usually acts as a schizont reproducing asexually producing asexual amoebulae. Such individuals are termed **microspheric**. The differences between the two forms are given in the table below :

Megalospheric	*Microspheric*
1. Proloculum large but thin-walled— diameter 60 – 100 mμ	1. Proloculum small but thick-walled— diameter about 10 mμ
2. Second chamber horn-shaped	2. Second chamber also spherical
3. Uninucleate	3. Muttinucleate
4. Gamont-Haploid	4. Schizont-Diploid
5. More common	5. Less common
6. Retral processes present in all chambers	6. Retral processes found in later chambers only
7. Relatively small in overall size	7. Relatively large in overall size.
8. Rotation of chambers counter-clockwise	8. Rotation of chambers clockwise

Owing to the existence of two types of individuals, different both structurally and functionally, *Elphidium* is said to be dimorphic. The phenomenon of dimorphism is also related to the alternation of one form with the other in the life-cycle of this foraminiferan protozoa.

Besides diatom, bacteria. and unicellular algae, *Elphidium* also feeds on other pratozoa and microcrustacea. Lee (1980) has reviewed the nutritional physiology of foraminifera. Exchange of gases occurs across the general body surface. The surface area of the extra-thalamus cytoplasm with its large number of pseudopodia is ideal for such exchanges. Excretory wastes in fluid form is removed through the general surface. Brown excretory granules—stercomata-are stored temporarily in the cytoplasm and extruded outside before the individual embarks on reproductive process.

1.15. Life-Cycle

The first attempt at a study of the life cycle of a foraminifera was made by **Schauddin** in 1900 Later **Lister** (1903) added some informations on the reproduction in *Polystomella* **Myers** (1938-40) made further observations and most of the earlier findings were confirmed by **Le Calvez** (1938, '50) who provided the first complete account of the life cycle of this genus. **Margaret Jepps** in 1962 gave a detailed account of the life cycle of *Polystomella* from the English Channel. **Grell** (1967) found that gametes in *Elphidium* are haploid and the amoebulae produced asexually by the microspheric individuals are diploid.

It is convenient to begin the study of the life-cycle of *Elphidium* with the microspheric form. The first indication of the onset of the reproductive process is :

(a) the great increase in the number of pseudopodia, resulting in the formation of a halo around the shell,

(b) the stercomata are expelled out from the shell.

Soon the entire cytoplasm comes out of the shell and is massed close to it. After some streaming movements the protoplasm gradually and simultaneously separates into spherical masses of uniform size. At the centre of each protoplasmic mass is a nucleus. In a short time each sphere called amoebula secretes a thin spherical calcareous shell of 60—100 *m*µ in diameter. This is the proloculum of the megalospheric form. The spherical shell has an opening through which the cytoplasm protrudes out in the form of a few pseudopodia. The megalospheric prolocula remain close together for sometime and then separate and draw apart. The entire protoplasm of the microspheric individual is used up in the formation of the brood of amoebulae. As the amoebulae feed and grow, the need arises to cover the grown out cytoplasm which now protrudes much beyond the initial chamber. A second chamber is secreted to cover this growing cytoplasm. This chamber is horn-shaped or semilunar. The second chamber of the growing megalospheric individual is provided with a few retral processes. The young megalosphere continues to feed and grow. Further chambers are added at the rate of 2 chambers/day.

After a week the single nucleus moves out of the megalospheric proloculum and comes to occupy the cytoplasm in the middle of the series of chambers. Schizogony in the microspheric individual begins in early spring and fully developed megalospheric forms are found by the end of summer.

The fully grown megalosphere embarks on sexual reproduction in the next spring. At the beginning of reproductive process

(a) pseudopodia are withdrawn

(b) xanthosomes loosen out

(c) single nucleus divides repeatedly forming many nuclei

(d) protoplasmic mass inside the shell is completely divided] into small masses, each mass surrounding a single haploid nucleus. Each uninucleate gamete develops a pair of unequal flagella. The gamete is 2-5 *m*µ in diameter.

These flagellate swarmers issue out of the megalospheric shell at about midnight in a milky stream. It is suggested that these gamętes undergo syngamy. The zygote with the diploid nucleus secretes a small thick-walled proloculum of about 10 $m\mu$ diameter. In early fall (autumn), half grown microspheric individuals are commonly found.Jepps believed that in the relatively coolar waters of the English Channel, *Elphidium* takes a span of two years to complete its life cycle involving an alternation of the microspheric schizont generation with the megalospheric gamont generation. In the warmer waters of Indian Ocean both the generations may be completed within a single year.

According to **Myers** (1943) growth and reproduction in *Elphidium* are geared to the spring peak in phytoplankton population on which this animal feeds. **Lee** (1980) has suggested that the pattern of natural life cycle in the foraminifera is tuned to the availability of food. The life-cycle of *Elphidium* is depicted in the figure below :

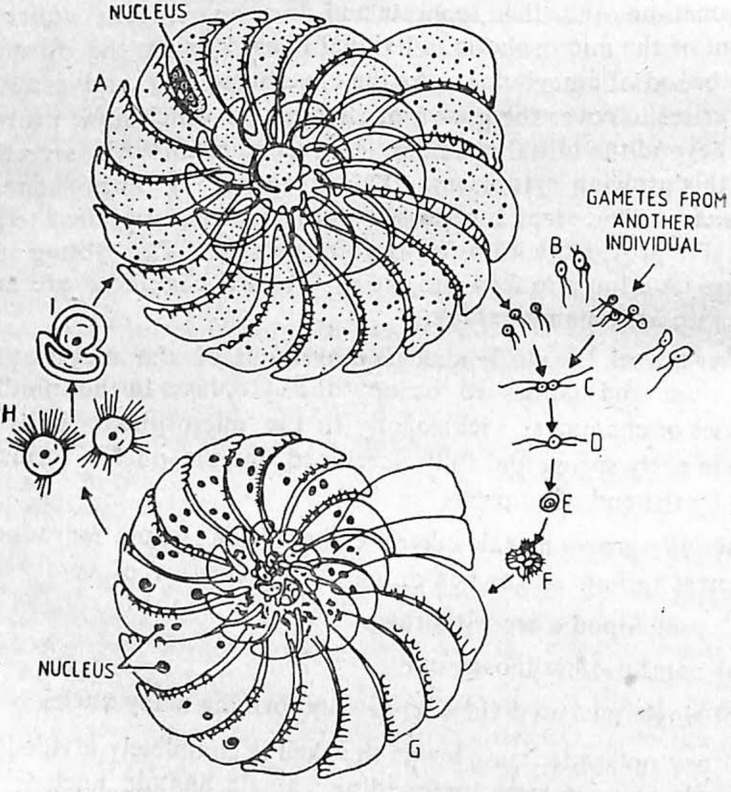


Fig. 1.24. *Elphidium* : Life cycle A. megalospheric individual; B. flagellated gametes. C-E. syngamy; F. young microspheric individual; G. mature microspheric individual; H.-I. young megalospheric individuals derived from microspheric individual

EUGLENA

1.16. Habitat—*Euglena* is a free-living solitary autotrophic flagellate containing chloroplast. It is found in rain puddles, ponds, ditches and sluggish streams which are stagnant containing fair amount of nitrogenous content caused by decay of organic matter. It is specially abundant during the rainy season giving the water a greenish colour.

1.17. Structure—The common species of *Euglena* are *E. viridis*, *E. gracilis* and *E. spirogyra.* Those found commonly in India include *E. orientalis*, *E. agilis* and *E. fusiformes*.

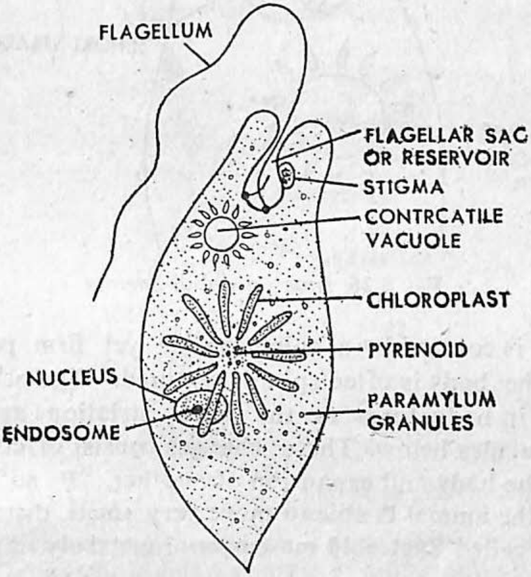


Fig. 1.25. *Euglena viridis*

Euglena has slender mostly elongate spindle-shaped body with a relatively blunt anterior end and a somewhat conical and pointed posterior end. At the anterior end is a funnel-shaped invagination. The opening is **cytostome** which leads into a spherical dilation through a short narrow tubule called **cytopharynx**. The dilation is often called the **reservoir** into which the **contractile vacuole** opens. From the posterior wall of the reservoir two **flagella** emerge from separate **blepharoplasts** or basal granule. One flagellum extends out of the invagination or **flagellar pocket**, the other is very short and ends within the pocket. Near the base of the long or free flagellum is a small lenticular swelling sensitive to light called photoreceptor.

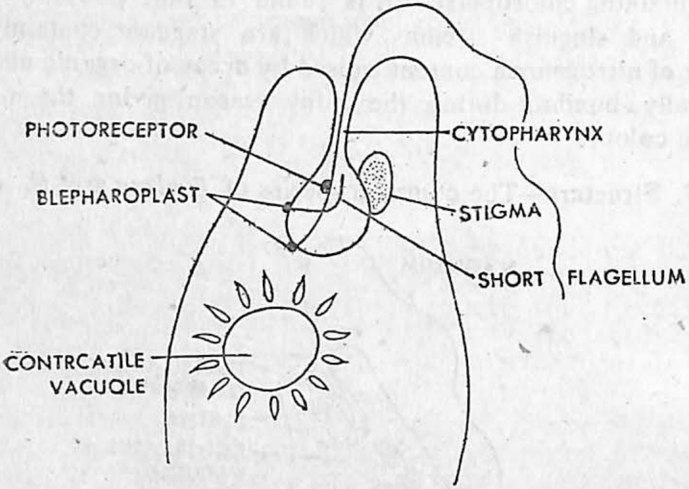


Fig. 1.26. Anterior end of *Euglena*

The body is covered by a thin, flexible yet firm pellicle. The surface of the body is often spirally textured. The pellicle permits some change in body form as the spiral striations are associated with microtubules below. These changes consist of contraction of one part of the body and expansion of another. By such changes in body shape the animal is able to move very small distances. Such movement is called **Euglenoid movement** or **metaboly.**

On the dorsal aspect of the reservoir or gullet is a red pigmented spot called **stigma** lying close to its wall. Experiments have shown that the stigma has only a shadow casting function. Light absorption which is a prerequisite for **phototaxis** (= orientation in response to light) occurs outside the stigma probably at the lenticular body or **photoreceptor (=paraflagellar body)** on the long flagellum. Experiments by **Gossel** (1957) and **Bunning** and co-workers (1956) indicate that the stigma has only a shadow casting function. Light absorption which is essential for phototaxis occurs outside the stigma by the photoreceptor at the base of the long flagellum.

A large **contractile vacuole** lies close to the ventral wall of the gullet slightly behind it. Surrounding this vacuole are a number of small **secondary vesicles** which pour their fluid into the main vacuole.

The fluid fills the contractile vacuole during its diastole which may last for about 30 seconds. The vacuole when full contracts (—systole) and empties its content into the reservoir or gullet from where it passes out.

A large number of **chromatophores** containing **chloroplast** are found in the cytoplasm. Their shape and disposition vary in the different species of *Euglena*. In *E. viridis* they are bar-shaped arranged radially from a common central area in a disposition which is called stellate. Each chloroplast consists of a central thin nonpigment area called pyrenophore which is surrounded by a pair of oval pyrenoid. The pyrenoid has a densely granular and fibrillar structure. Paramylum granules are deposited on the pyrenoid.

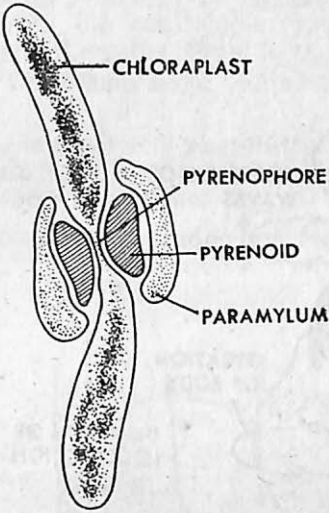


Fig. 1.27. Chloroplast, pyrenoid and paramylum in *Euglena*

A large spherical vesicular nucleus containing a large central endosome is located towards the posterior half of the body. Exposure of *E. gracilis* to high temperature ($32-35°C$), weak $U-V$ radiation and some drugs causes the conversion of chloroplast to colourless leucoplast.

1.18. Locomotion—*Euglena* largely moves with the help of its flagellum. The flagellum beats in undulating motions either wholly in one plane (uniplanar or **sinusoidal** or in the form of a helix (**helicoidal**). The water pressure which propels *Euglena* is created by these sinusoidal or helicoidal waves which usually move from the base to the tip of the flagellum which is usually directed backward during swimming and the animal is propelled forward Often no sharp distinction can be made between planar undulations and helical waves. They may be superimposed so **Euglena** often moves forward, in water with a screw like motion with spiral rotation of the body. From anterior to posterior a peristaltic expansion and contraction of the body aided by pellicular microtubules enables limited degree of locomotion. This is Euglenoid movement or metaboly. By this method *Euglena* can move only when it is in contact with substratum.

1.19. Nutrition—*Euglena* obtains its nutrition by a combination of autotrophic and heterotrophic methods and is therefore called mixtotrophic.

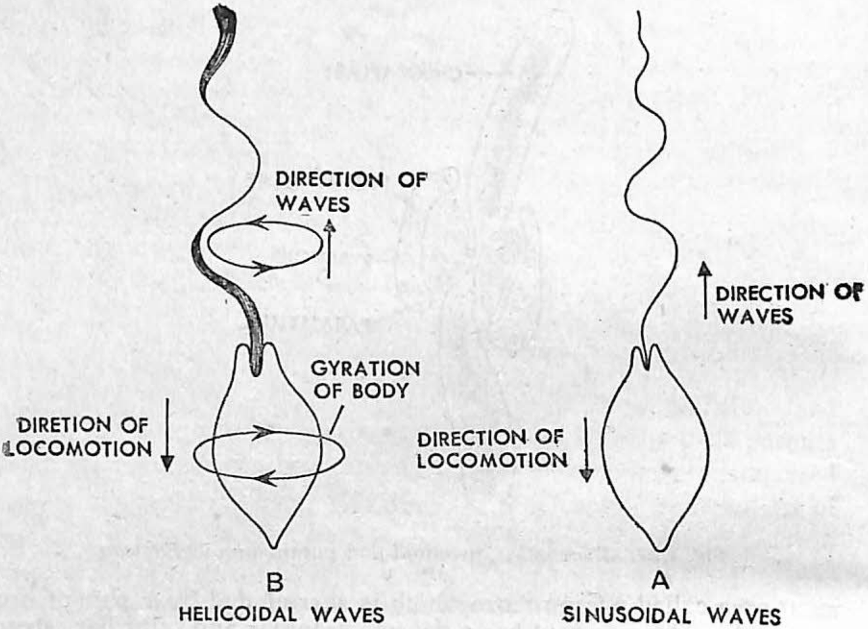


Fig. 1.28. Diagram explaining flagellar locomotion in *Euglena*

1. Autotrophic or holophytic method—*Euglena* possesses chloroplast containing chlorophyll a and b as well as carotenes. In sunlight the animal synthesises a β—1:3 glucan starch called paramylum which is usually deposited close to the pyrenoid. However, many species of *Euglena* can grow heterotrophically in dark. According to **Hell** (1967) *E. gracilis* can utilise CO_2, acetate and ethanol as carbon sources, and NH_4+, $NO_3^=$ and NO_2^- as nitrogen sources. They require Vit. B_{12}. Thus they have few organic requirements even for heterotrophic nutrition and possess extensive synthetic ability.

2. Saprophytic Method—*Euglena* can absorb nutrients from a nutrient medium across its body surface. It can absorb simple nutrients derived from decay of organic matter in the water. *Euglena* secretes some intracellular proteolytic enzyme of typical animal characteristics.

Claims of holozoic nutrition with ingestion at the cytostome are yet to be substantiated.

1.20. Respiration—*Euglena* is aerobic relying largely on O_2 of photosynthetic origin during day. During night it obtains O_2 from the ambient water.

Excretion—Both CO_2 and nitrogen wastes diffuse out of the body at the body surface.

Osmoregulation—Excess of water in the body is expelled by the contractile vacuole. Some soluble excretory wastes are also removed with fluid expelled from the contractile vacuole to the outside through the reservoir and the gullet. Fluid in the contractile vacuole accumulates gradually from many small secondary vesicles surrounding the former.

Behaviour—*Euglena* is negatively phototactic to intense light but moves towards moderate light. It orientates itself parallel to a beam of light and swims towards the source.

1.21. Reproduction—When environmental factors are favourable

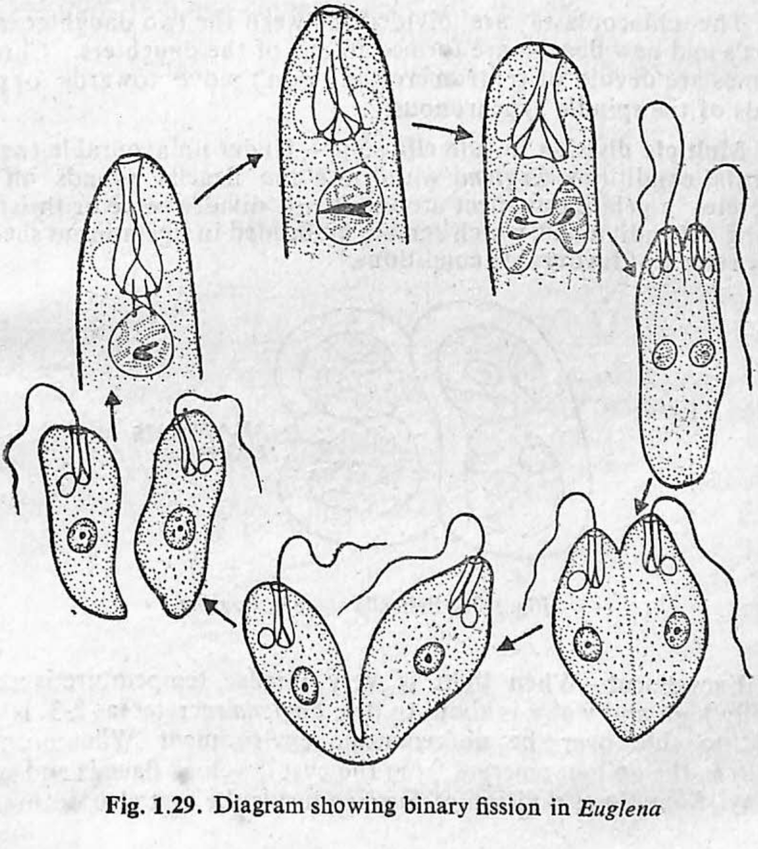


Fig. 1.29. Diagram showing binary fission in *Euglena*

Euglena multiplies by longitudinal binary fission which has been studied by **Leedale** (1968). Evidence for the impending division of the body appears when new pellicle ridges appear between the existing ones which occurs before the onset of nuclear division. The stages of binary fission are :

(i) Nucleus increases in size, chromosomes appear.

(ii) The reservoir and gullet divide into two.

(iii) An internal spindle of microtubules is formed with the nuclear membrane continuing to surround it.

(iv) Blepharoplast and stigma divide.

(v) A new contractile vacuole is formed.

(vi) Chromosomes settle at the middle of the spindle.

(vii) Nucleus divides into two.

(viii) Cytoplasm starts dividing from the anterior end progressing toward the posterior resulting in the formation of two daughter *Euglena*.

The chloroplasts are divided between the two daughter individuals and new flagella are formed in one of the daughters. Chromosomes are devoid of centromeres and don't move towards opposite ends of the spindle synchronously.

Multiple division in palmella stage—Under unfavourable environmental conditions, *Euglena* withdraws the flagella rounds off and secretes a gelatinous sheet around it. It divides twice or thrice forming 4-8 individuals which remain embedded in a gelatinous sheet till the return of favourable conditions.

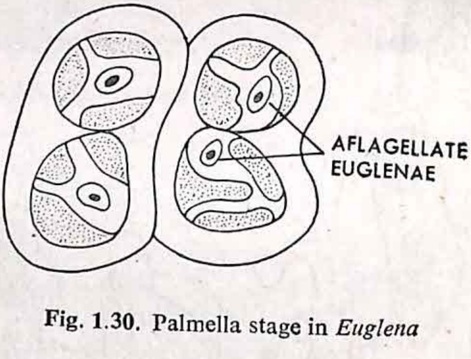


Fig. 1.30. Palmella stage in *Euglena*

Encystment—When light is very intense, temperature is abnormally high and water is about to dry, *Euglena* secretes a 2-3 layered cyst to tide over the unfavourable environment. When normalcy returns the animal emerges from the cyst develops flagella and swims away. Sometimes division of *Euglena* inside the cyst also occurs.

1.22. Why is *Euglena* included in the kingdom Animalia ?

Euglena is often included by botanists among unicellular algae in the order **Euglenophyceae** because of the presence of chloroplast, pyrenoid and holophytic nutrition. It is included in class **Mastigophora** and considered an animal because :

1. The body is covered with a proteinaceous pellicle and not with cellulose.

2. Nutrition is **mixotrophic** and the cytostome may be used in related forms for ingestion of food in typical animal fashion.

3. When chloroplast is destroyed by exposing the organism to UV radiation or high temperature it can live saprophytically.

4. Contractile vacuole and photoreceptor are present in *Euglena.*

5. Occurrence of longitudinal binary fission.

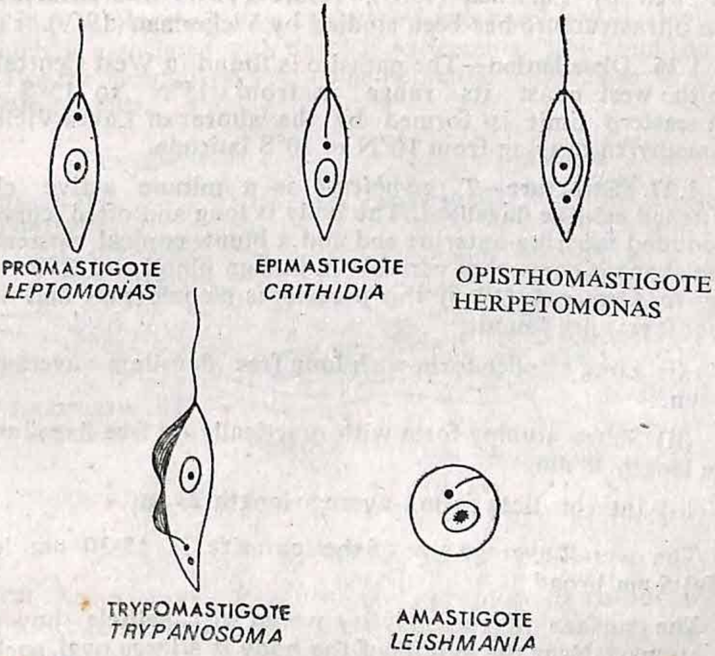
6. Absence of sexual reproduction.

1.23. Haemoflagellates—The flagellates parasitic in blood, lymph, lymph glands and cells of reticuloendothelial system in man and domestic animals are referred to as haemoflagellates. Some of them cause dreadful diseases and are transmitted from host to host through the agency of blood sucking invertebrate intermediate host.

1.24. Important human haemoflagellates include :

(i) *Trypanosoma,* (ii) *Leishmania.*

The various forms of haemoflagellates are given in the sketch below.



PROMASTIGOTE *LEPTOMONAS*

EPIMASTIGOTE *CRITHIDIA*

OPISTHOMASTIGOTE HERPETOMONAS

TRYPOMASTIGOTE *TRYPANOSOMA*

AMASTIGOTE *LEISHMANIA*

Fig. 1.31. Types of flagellate forms found among haemoflagellates

Trypanosoma—Three species of this genus namely—

(i) *T. gambiense* (ii) *T. rhodesiense*	Causing sleeping sickness or Trypanosomiasis.
(iii) *T. cruzi*	causing Chagas' disease is pathogenic in human being.

TRYPANOSOMA GAMBIENSE

1.25. History—Trypanosomes were first seen in 1841 and the genus *Trypanosoma* was created by **Gruby** in 1843. Some of the early findings of pathogenic trypanosomes related to those found in animals (**Evans,** 1880; **Bruce** 1895). The first human trypanosome was reported by **Forde** (1901) in a case of Gambian fever, and **Dutton** (1902) named the parasite *Trypanosoma gambiense*. A year later **Castellani** found them in cerebrospinal fluid (CSF) of man suffering from sleeping sickness. **Kleine** (1909) discovered that tse-tse fly *Glossina palpalis* is the intermediate host for this parasite. The life-cycle in the fly was first studied by **Kleine, Bruce** and **Nabarro,** and **Minchin** durring 1908 to 1912. **Stephens** and **Fantham** (1910) distinguished *T. rhodesiense* from *T. gambiense.* The first complete account of the life-cycle was provided by **Robertson** (1913). **Vickerman** (1962) reinvestigated the life-cycle of the *brucei* group to which this species also belongs. The biology of the parasite and its pathogenecity has been reviewed by **Lumsden** (1965), **Hoare** (1967) and **Ormerod** (1971). The ultrastructure has been studied by **Vickerman** (1969).

1.26. Distribution—The parasite is found in West Central Africa. On the west coast its range is from 15°N to 15°S latitude, the eastern limit is formed by the shores of Lakes Victoria and Tanganyika ranging from 10°N to 10°S latitude.

1.27. Structure—*T. gambiense* is a minute active elongated flattened eel-like flagellate. The body is long and often curved with a pointed tapering anterior end and a blunt conical posterior end. The shape is somewhat variable in human blood and CSF. According to **Ormerod** (1967) this parasite is pleomorphic and three distinct forms are found :

(i) Long slender form with long free flagellum—average length 29 µm.

(ii) Short stumpy form with practically no free flagellum—average length 18 µm.

(iii) Intermediate form—average length 23 µm

The overall average size of the parasite is 15-30 µm long and 1·5-3·5 µm broad.

The surface of the body is covered with **pellicle** showing spiral striations. Near the middle of the body is a large oval **nucleus** with a prominent central **endosome.** A **kinetoplast** consisting largely of

DNA is located near the posterior end. A blepharoplast is situated close to the **kinetoplast.** **Axoneme** consisting of microtubule, arises from the blepheroplast. The basal part of the axoneme is enclosed in a flagellar pocket which can be seen only under Electron Microscope.

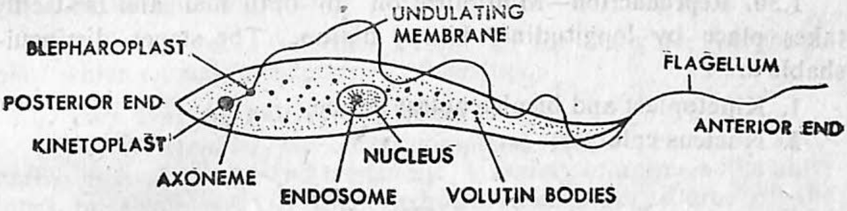


Fig. 1.32. Strutucre of *Trypanosoma gambiense*

The axoneme emerges from the pocket ensheathed with cytoplasm forming a flagellum which runs anteriorily attached to the body by a thin periplastic membranelle forming undulating membrane. At the anterior end the flagellum extends out free of the body.

Metachromatic **volutin granules** are scattered in the cytoplasm. They are stores of RNA and polyphosphates important during binary fission.

The electron micrograph of *Trypanosoma* shows the presence of a single long and narrow mitochondrion with the kinetoplast located inside it. The **blepharoplast** consists of two basal bodies, only one of which is associated with flagellar axoneme arising from the basal body I in the flagellar pocket. The pellicular ridges are associated with microtubules.

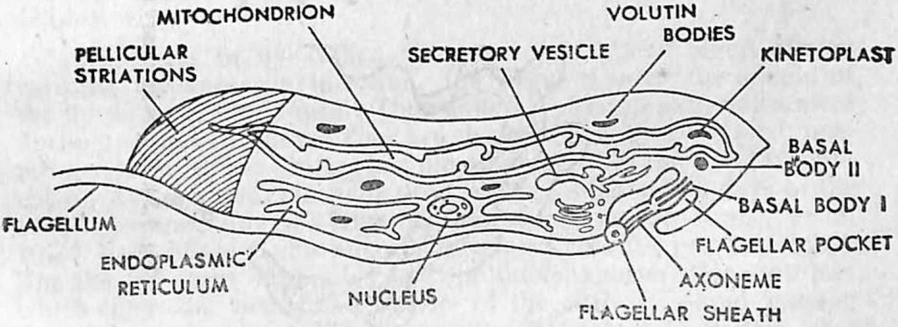


Fig. 1.33. Ultrastructure of *Trypanosoma*

Biology

1.28. **Locomotion**—Trypanosomes are more numerous in lymph and CSF than in blood. In these habitats they actively move by wavy motions of the body, the undulating membrane as well as the undulations of the flagellum.

1.29. Nutrition—*T. gambiense* is saprozoic obtaining glucose, fructose and glycerol from blood plasma etc. The parasite lives in a medium with large glucose supply (**Southworth** and **Read,** 1969).

1.30. Reproduction—Multiplication in both man and tse-tse fly takes place by longitudinal binary fission. The stages distinguishable are :

1. Kinetoplast and blepharoplast divide.
2. Nucleus enlarges.

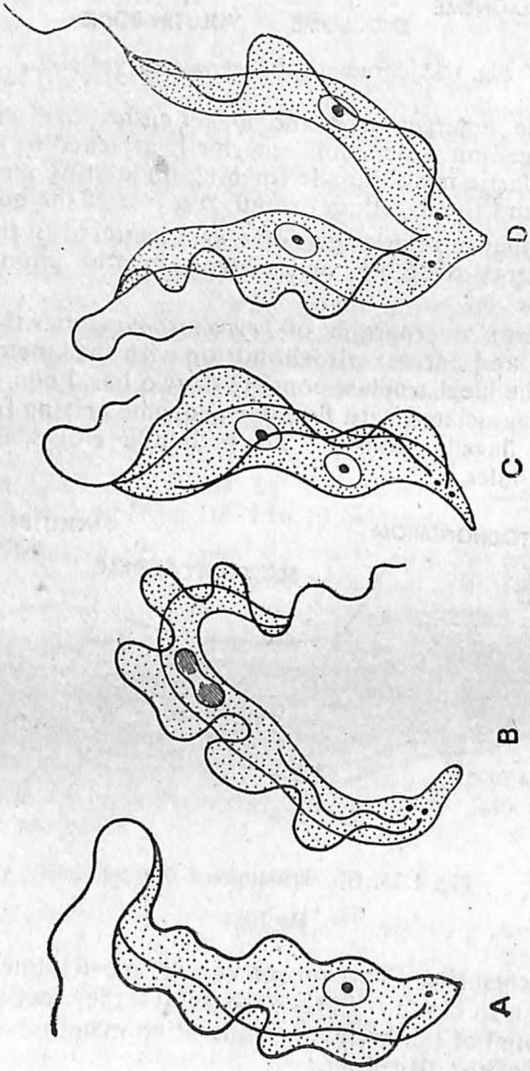


Fig. 1.34. Stages in binary fission in *Trypanosoma*

3. Intranuclear spindle of microtubules is formed (**Vickerman** and **Preston**, 1970).

4. Cytoplasm starts dividing, the cleavage extending from the posterior to the anterior end.

5. A new axoneme is formed by one of the daughter blepharoplast which extends and forms the flagellum.

6. Two daughter individuals separate.

1.31. Life-cycle—*T. gambiense* completes its life-cycle in two alternating hosts viz. man and tse-tse fly. A variety of animals like antelopes, hogs etc. serve as reservoir hosts—a constant source of the parasite.

1.32. Cycle in man—In human being the parasite is found in blood and lymph in the early stages of the disease. Man gets infection when an infective tse-tse fly usually **Glossina palpalis** containing metacyclic trypanosomes injects the parasite along with saliva during its bite to suck blood. After entry in human body the parasite multiplies at first at the site of the bite. It appears in blood stream after seven days.

In blood the trypanosomes divide to produce a variety of forms which can be distinguished into three types. Slender forms are more common in severe infection. They reach the lymph glands causing local proliferation of phagocyte leading to their enlargement. Some trypanosomes may disappear due to trypanolytic antibodies but reappear later as more resistant forms. In about three months trypanosomes invade the cerebrospinal fluid and later enter brain causing brain damage leading to general physical and mental depression.

1.33. Cycle in fly—When the tse-tse fly sucks blood of man carrying trypanosome infection, the parasite enters the midgut of the fly with the blood meal. They undergo physiological adjustment during the first two days. They are characterized by a pointed posterior end with the kinetoplast placed away from the tip. Multiplication by repeated binary fissions continues from 2-10 days of the blood meal resulting in a large number of long slender forms. From 10-15 days these forms migrate anteriorily into the proventriculus. The slender form multiplies and produces shorter trypanosomes which enter the ducts and lumen of the salivary gland passing though hypopharynx and labial cavity. This occurs 12-20 days after the first blood meal. The newly-arrived form in the salivary gland continues to multiply. During the salivary gland phase the trypanosomes change into crithidia (epimastigote) type. The crithidia also divide rapidly from 15-20 days after the parasite's entry in tse-tse fly. Ultimately (20-30 days) the crithidia change into trypaniform (trypomastigote) individuals. These are called metacyclic forms having a distinctly curved body and a more wavy undulating membrane. When a tse-tse fly with trypanosomes blocking its salivary duct and gland bites a human host, it pushes the parasite into his blood along with its saliva before it starts sucking blood.

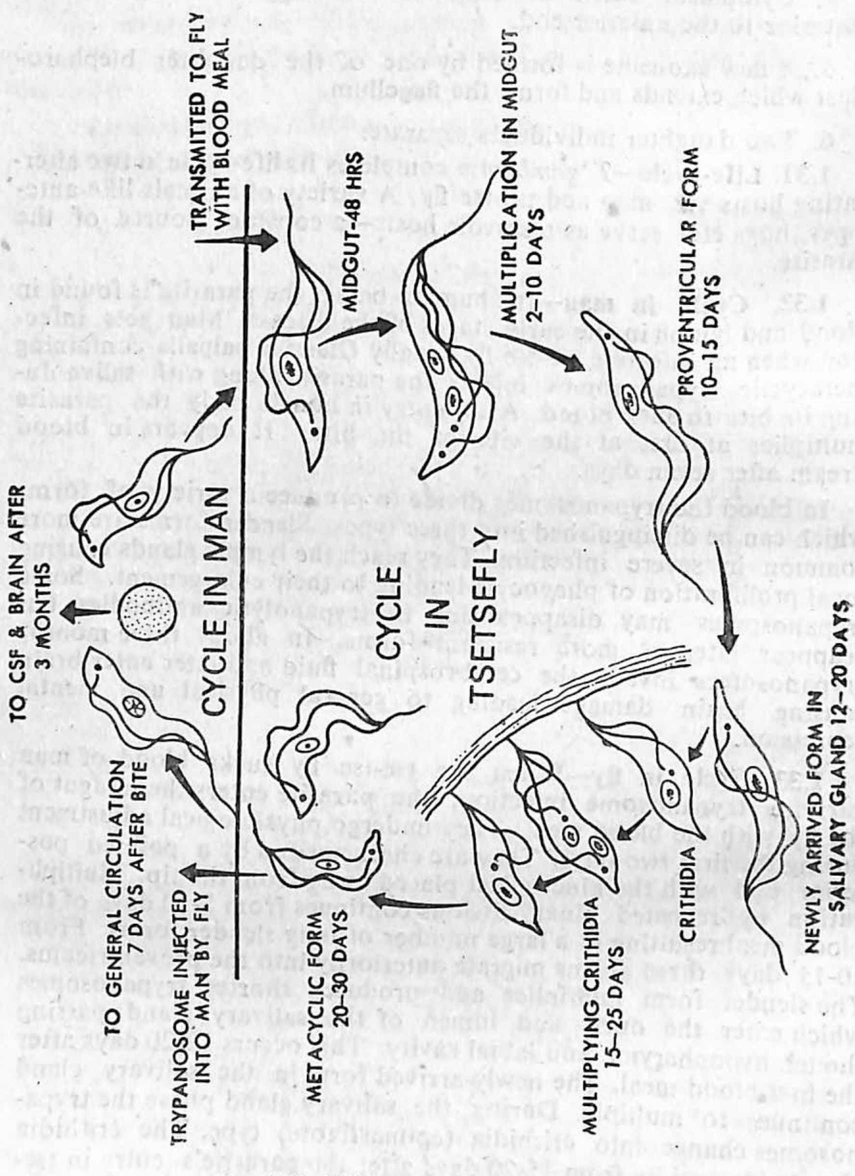

TO CSF & BRAIN AFTER 3 MONTHS
TO GENERAL CIRCULATION 7 DAYS AFTER BITE
TRYPANOSOME INJECTED INTO MAN BY FLY
TRANSMITTED TO FLY WITH BLOOD MEAL
CYCLE IN MAN
METACYCLIC FORM 20–30 DAYS
MIDGUT-48 HRS
CYCLE IN TSETSEFLY
MULTIPLICATION IN MIDGUT 2–10 DAYS
MULTIPLYING CRITHIDIA 15–25 DAYS
PROVENTRICULAR FORM 10–15 DAYS
CRITHIDIA
NEWLY ARRIVED FORM IN SALIVARY GLAND 12–20 DAYS

Fig. 1.35. Life-cycle of *T. gambiense.*

Of a large number of fly feedings on blood of persons suffering from sleeping sickness only 0·1—0·2% become infective. The optimum temperature for completion of the cycle in the fly is 23°30°C. The duration of the cycle in fly is temperature dependent.

1.34. Transmission—The parasite is transmitted from man to man through the agency of tse-tse fly. Transmission is cyclical and inoculative.

G. palpalis is the most common vector, but occasionally *G. morsitans* can spread the parasite. Direct inoculative transmission within two hours of the blood meal is possible if some parasites are still stuck up in the probocis.

1.35. Pathogenicity—*T. gambiense* causes acute, chronic or latent disease depending on the species of the vertebrate host and virulence of the strain. It causes irregular fever, enlargement of lymph glands, increase in CSF, damage to brain etc. If left untreated the disease proves fatal.

T. gambiense produces the following pathological changes :

(a) Blood—ESR is increased; Coagulation time is reduced; Serum Ca^{++} is lowered; RBC becomes more fragile; Albumin/globulin ratio is altered and even reversed.

(b) Glands—Neck glands and spleen are enlarged.

(c) Central Nervous System—CSF is increased. Brain tissue is damaged by perivascular deposition of toxic substances.

LEISHMANIA

1.36. The genus *Leishmania* like *Trypanosoma* is a haemoflagellate which occurs in the vertebrate host as amastigote form without flagellum and in the intermediate blood sucking vector as promastigote form. Three very closely similar species are commonly pathogenic to man. They are :

(i) *Leishmania donovani*—parasitic in reticulo-endothelial cells of visceral organs specially spleen causing **Kala Azar** or visceral leishmaniasis.

(ii) *Leishmania tropica*—parasitic in blood and reticuloendothelial cells in the skin causing **Oriental** or Baghdad **sore**—cutaneous leishmaniasis.

(iii) *Leishmania brasiliensis*—parasitic in cutaneous and mucocutaneous parts causing **Espundia or** mucosal leishmaniasis.

LEISHMANIA DONOVANI

1.37. Structure—*L. donovani* occurs in man as an **amastigote** form. It is very small, round or oval 2-5 μm in diameter. Under light microscope a centrally placed nucleus is seen. To one side of the nucleus is a rod-shaped kinetoplast. Sometimes a basal body is also seen. The electron microscope reveals a structure comparable to that of a **trypomastigote** with a single mitochondria, Golgi apparatus and endoplasmic reticulum. The mitochondrion is however poorly developed in the amastigote. The kinetoplast is composed of DNA and is situated within the mitochondrion. An axoneme composed of typical arrangement of microtubule is also seen.

Leishmania appears as a flagellate individual a promastigote or leptomonad form in the body of the intermediate host the sand fly, *Phlebotomus argentipes*. The leptomonad form has an elongated elliptical body 14-20 μm long and 1·5-3·5 μm broad. A round or oval nucleus is placed near the centre of the body. An oval kinetoplast lies transversely near the anterior tip of the body, ahead of which is a small blepharoplast from which a free flagellum emerges out. Under the electron microscope the leptomonad stage shows a prominent curved mitochondrion with a prominent kinetoplast inside near its anterior end. Microtubules are found below the pellicle as they are in the amastigote form also. When the leishman bodies (=amastigote form) are cultured in the laboratory they readily change into the leptomonad (=promastigote) form.

1.38. Biology—The parasite absorbs nourishment from the cell it parasitises, or from the content of the gut when it is in the sand fly. It can utilize glucose, fructose, maltose and glycerol.

Multiplication—Both the leishman and leptomonad forms are reproduced by binary fission which is distinctly longitudinal in the leptomonad.

Inside human cells *L. donovani* multiplies by repeated binary fissions and often a cluster of 50-200 parasites may be found inside a single enlarged cell. Ultimately the host cell ruptures liberating the parasites into the tissue spaces from where they invade fresh host cell.

The leptomonads may also sometimes divide by repeated binary fissions often forming rosettes of the flagellate parasite.

1.39. Life-cycle—*L. donovani* was discovered in human blood by **Leishman** and **Donovan** in 1903.

Cycle in man—*L. donovani* lives inside the cells of reticuloendothelial system. It appears to be well-adapted to a life inside these cells and the hosts' proteolytic enzymes do not seem to destroy it. Within the macrophages (a RE Cell) the leishman body divides by binary fission once in every 24 hours. The parasite usually strikes the macrophages in the liver and spleen. When a sand fly sucks blood from a man suffering from Kala-azar it ingests a few leishman bodies either free or within the macrophages.

Cycle in fly—Within the gut of the sand fly the leishman (=amastigote) bodies change into the leptomonad (=prom astigote) form in about 24-36 hours of the infective blood meal. The leptomonad embarks on rapid multiplication by repeated longitudinal binary fission in the midgut during 4-5 days of the blood meal. Soon the parasite migrates forward and the foregut is occupied by the flagellate parasite. It gradually moves into the salivary gland by 7-8 days. Unlike *Trypanosoma gambiense* the development of *L. donovani* in the invertebrate host is confined to the foregut.

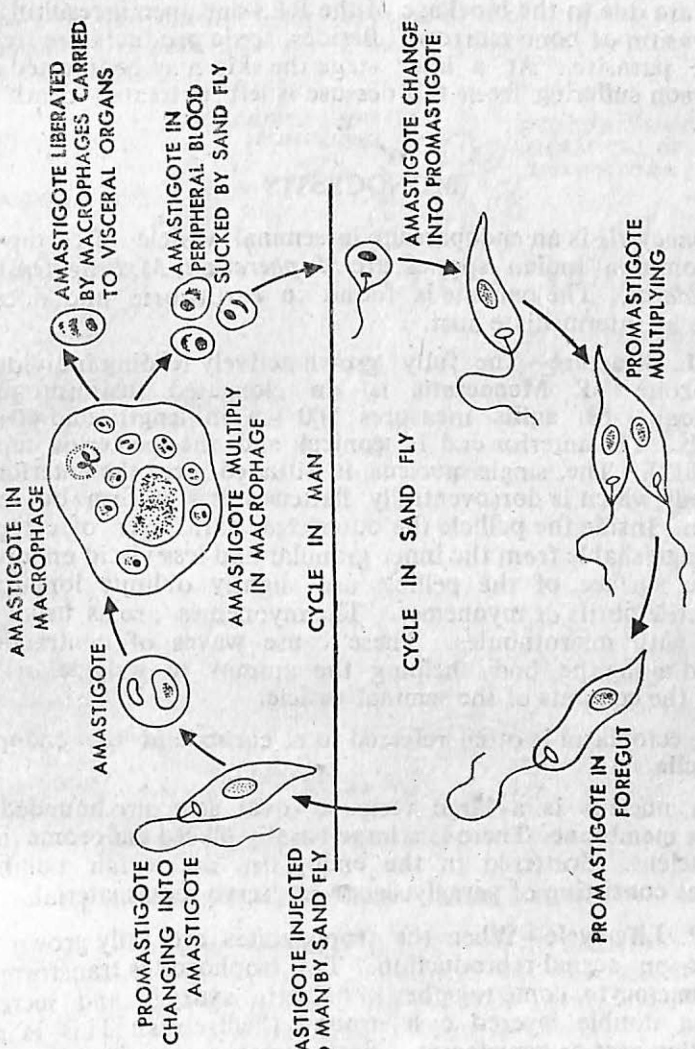

AMASTIGOTE
AMASTIGOTE IN MACROPHAGE
AMASTIGOTE LIBERATED BY MACROPHAGES CARRIED TO VISCERAL ORGANS
AMASTIGOTE IN PERIPHERAL BLOOD SUCKED BY SAND FLY
AMASTIGOTE MULTIPLY IN MACROPHAGE
CYCLE IN MAN
CYCLE IN SAND FLY
AMASTIGOTE CHANGE INTO PROMASTIGOTE
PROMASTIGOTE MULTIPLYING
PROMASTIGOTE IN FOREGUT
PROMASTIGOTE INJECTED INTO MAN BY SAND FLY
PROMASTIGOTE CHANGING INTO AMASTIGOTE

Fig. 1.36. Life Cycle of *Leishmania donovani*

Transmission—It was only in 1942 that it was proved that *L. donovani* is transmitted by the bite of infective sand fly *Phlebotomus argentipes.* A variety of hosts apparently unharmed by the parasite act as reservoir of this parasite.

1.40. Pathogenicity—*L. donovani* infection in man starts as a primary lesion in the skin. After 4-6 months the parasite spreads to the viscera with a preference for spleen, liver, and bone-marrow infecting the cells of the reticulo-endothelial system. The harmful effects are due to the blockage of the RES and anemia resulting from the invasion of bone marrow. Besides, toxic products are released by the parasite. At a later stage the skin may be infected and if the person suffering from this desease is left untreated death often results.

MONOCYSTIS

Monocystis is an endoparasite in seminal vesicle of earthworms. The common Indian species are *M. pheretimi*, *M. bengalensis* and *M. beddardi*. The parasite is found in earthworm and does not require an intermediate host.

1.41. Structure—The fully grown actively feeding individual or trophozoite of **Monocystis** is an elongated fusiform minute sporozoan. **M. agilis** measures 500 µm in length and 40 µm in breadth. The anterior end is conical and the posterior tapering (Fig. 1.12). The single nucleus is situated near the anterior end. The body which is dorsoventrally flattened has a firm but elastic pellicle. Inside the pellicle the outer clear thin layer of ectoplasm is distinguishable from the inner granular and less viscid endoplasm. On the surface of the pellicle are slightly oblique longitudinal contractile fibrils or myonemes. The myonemes are as usual associated with microtubules. These cause waves of contraction to proceed along the body helping the animal to wriggle or glide among the contents of the seminal vesicle.

The ectoplasm is often referred to as **cortex** and the endoplasm as **medulla.**

The nucleus is a large vesicular oval structure bounded by a nuclear membrane. There is a large basally placed endosome inside the nucleus. Scattered in the endoplasm are a fair number of granules consisting of **paraglycogen**—a reserve food material.

1.42. Life-cycle—When the trophozoites are fully grown they embark on sexual reproduction. Two trophozoites transform into oval **gametocyte,** come together in pairs in **synzygy** and secrete a common double layered cyst around themselves. This is called **association cyst** or **gametocyst**. Each gametocyte undergoes a process of gamete formation or gametogony. A large number of gametes are formed by a process of **syntomy** i.e. the single nucleus of each gametocyte divides repeatedly giving rise to numerous nuclei. The last nuclear division is reductional so the gametic nucleus is haploid. The haploid nuclei migrate to the surface of their parent gametocyte. A mass of cytoplasm gathers round each nucleus consequently the gametocyte gives a mulberry-like appearance Finally these tiny projections each with a nucleus separate leavin, some residual cytoplasm in each gametocyte. The gametes are set free in the assocation cyst. Equal number of gametes are produced by each gametocyte. In most species of **Monocystis** the gametes are similar, but in **M. mrazeki** one of the gametocytes produces flagellate gamete and the gametes produced by the two gametocytes are dissimilar.

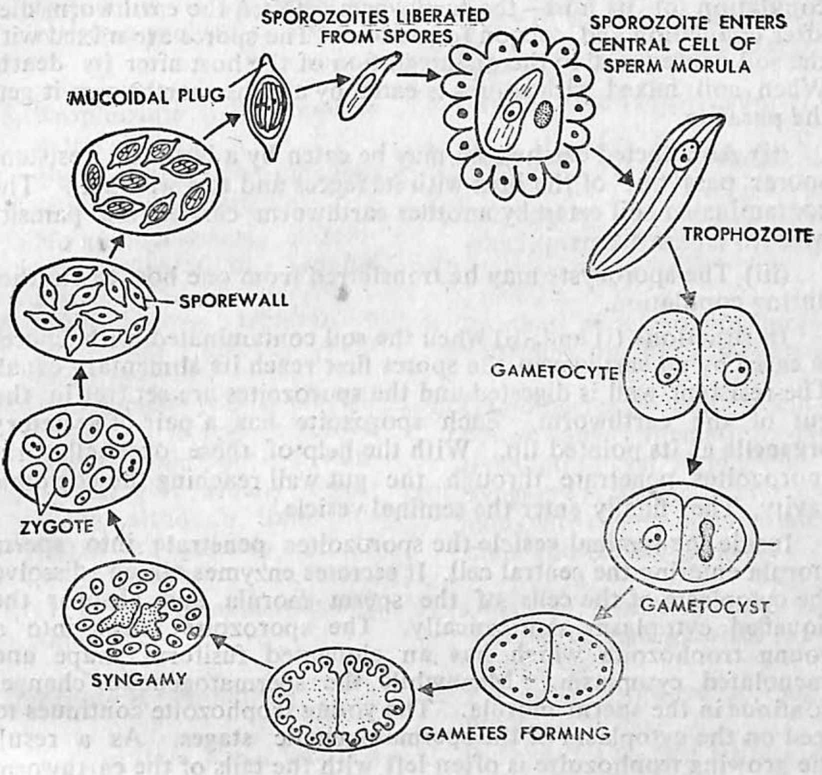


Fig. 1.37. Life-cycle of *Monocystis* (Diagrammatic)

The gametes undergo **syngamy** giving rise to numerous small fusiform diploid **zygotes.** Gametes produced by one gametocyte fuse only with the gametes produced by the other gametocyte. Each zygote secretes a single-layered tough covering or **sporocyst.**

Within each sporocyst or spore case the synkaryon (zygote nucleus) divides thrice yielding eight nuclei. Around each of these eight nuclei a thin strip of cytoplasm aggregates which finally separates into eight sickle-shaped or fusiform uninucleate **sporozoite.** The sporocysts assume the shape of a diatom, *Navicella* and is therefore called **pseudonavicella** stage.

The spores do not develop any further unless they are taken up by another earthworm. The spores containing the sporozoite are liberated in the seminal vesicle of the earthworm by disintegration of the parental gametocyst. The spore is the infective stage of *Monocystis*.

1.43. Transmission—There are a number of possibilities by which the spore reaches a fresh earthworm. These include :

(i) The cycle of the parasite is tuned with the maturation and copulation of its host—the earthworm. Often the earthworm dies after copulation and cocoon formation. The spores are mixed with the soil consequent to the disintegration of the host after its death. When soil mixed with spores is eaten by another earthworm it gets the parasite.

(ii) An infected earthworm may be eaten by a bird, the resistant spores pass out of the bird with its faeces and mix with soil. The contaminated soil eaten by another earthworm carries the parasite with it.

(iii) The sporocysts may be transferred from one host to another during copulation.

In situations (i) and (ii) when the soil contaminated with spores is eaten by an earthworm the spores first reach its alimentary canal. The resistant wall is digested and the sporozoites are set free in the gut of the earthworm. Each sporozoite has a pair of **secretory organelle** at its pointed tip. With the help of these organelles the sporozoites penetrate through the gut wall reaching the coelomic cavity. They finally enter the seminal vesicle.

Inside the seminal vesicle the sporozoites penetrate into sperm morula entering the central cell. It secretes enzymes which dissolve the cytoplasm of the cells of the sperm morula and absorbs the liquefied cytoplasm saprozoically. The sporozoite grows into a young trophozoite which has an elongated fusiform shape and vacuolated cytoplasm. Meanwhile the spermatogenetic changes continue in the sperm morula. The young trophozoite continues to feed on the cytoplasm of the spermatogenetic stages. As a result the growing trophozoite is often left with the tails of the earthworm sperms sticking to it. The fully grown trophozoite frees itself of the sperm tail and comes to lie free in the seminal vesicle. It has meanwhile accumulated plenty of reserves paraglycogen granules. The trophozoites then round off and join in pairs to embark on gamogony leading to the formation of gametes and syngamy.

1.44. Comparison of *Monocystis* with *Plasmodium*.

Monocystis	*Plasmodium*
1. Monogenetic—Life-cycle is completed within a single host—earthworm.	1. Digenetic—Life-cycle is completed in two hosts man and female *Anopheles*.
2. No intermediate host.	2. Female *Anopheles* is intermediate host as well as vector.

Manocystis	*Plasmodium*
3. Transmission from host to host is direct by contaminative method.	3. Intermediate host transmits the parasite to man by cyclical inoculative method.
4. The infective stage, the sporozoite is contained in a resistant protective case.	4. The infective stage, sporozoite is not free-living outside the body of the intermediate host, so it is not encased in resistant cyst.
5. Trophozoite is mostly extracellular.	5. Trophozoite is intracellular.
6. Fully-grown trophozoite is a minute vermicule.	6. Fully-grown trophozoite is rounded.
7. No asexual process or schizogony in adult trophic phase.	7. Schizogony is well-marked which precedes sexual process.
8. Fully grown trophozoite transforms directly into gametocyte.	8. Products of schizogony merozoite develop into gametocyte.
9. Two gametocytes come together in syzygy within a single double layer cyst-wall.	9. Gametocytes do not associate before gamete formation. No ossociation cyst formation.
10. Syngamy is usually isogamous, although trend towards anisogamy is seen in some species.	10. Syngamy is distinctly anisogamous with clearly differentiated male and female gametes.
11. Gametes are numerous and similar.	11. Only one female gamete but number of male gametes is 5-8 on average.
12. Zygote is non-motile.	12. Zygote is motile called Ookinete.
13. Sporozoites are contained in resistant sporocyst.	13. Sporozoites lie free within the body of mosquito.
14. Each sporocyst or spore contains 8 sporozoites.	14. Sporozoites are very numerous.
15. Life-cycle consists of syngamy followed by sporogony.	15. Life-cycle consists of schizogony (in man) followed by syngamy and sporogony (in female *Anopheles*)
16. There is no incubation period as the parasite multiplies only after growing fully in the host.	16. There is a distinct incubation period, during which only pre-erythrocytic schizogony in liver cells takes place.
17. The parasite is not pathogenic to its host.	17. Plasmodium is the causative agent of malaria in man. The mosquito is unharmed.

VORTICELLA

1.45. Habit and Habitat—*Vorticella* is found in fresh water pools, springs, ponds and streams which have fair amount of organic materials but are not very stagnant. Most species are **mesosaprobic** i.e. live in water with moderate organic and nitrogenous content. *V. microstoma* is however found in polysaprobic medium very rich in organic content. *Vorticella* is a sessile solitary stalked form found attached to leaves and stems of submerged water plants and epizoic (attached on the body) on various fresh water animals. They habitually feed on bacteria. A number of species appearr in sewage treatment system.

1.46. Structure—*Vorticella* popularly called bell-animalcule has the form of an inverted bell. The body is attached by a stalk which is long, thin and highly contractile.

The body is broad and more or less flat at its free end. Its margin is thick and folded downward forming a **collar**. The flat apical surface is called the **peristome**. The collar is continuous with peristome except for a **vestibule**. The vestibule is a conical depression having a **cytostome** at its base near the middle of the solid bell-shaped body.

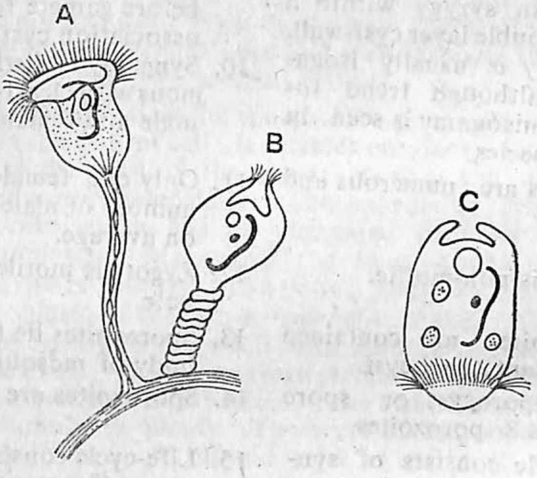


Fig. 1.38. *Vorticella*. A—Stalk fully extended. B—Stalk contracted into tight spiral. C—Telotroch—Free swimming stage

Ciliation—Cilia are found only in the **peristomial disc** and in the vestibule. The periphery of the peristome has two circlets of cilia, an inner whorl and an outer whorl. Both these ciliated tracts enter the vestibule. In the vestibule the cilia of the outer circlet are long and closely placed forming an **undulating membrane**. The cilia of the inner whorl are composed of two rows of cilia, the outer whorl has only a single row. Ciliation in *Vorticella* has been studied by **Noland** and **Finley** (1931). According to **Lom** (1964) the outer whorl has two rows of kinetosome (basal body) one of which is barren i.e. does not support cilia.

Body—The top end of the body is broad which gradually narrows to a conical part called **scopula.** The collar is thick and contractile. Between the peristomial disc and collar is a shallow **peristomial groove.** The body in the various species of *Vorticella* ranges in size from 40-100 µm.

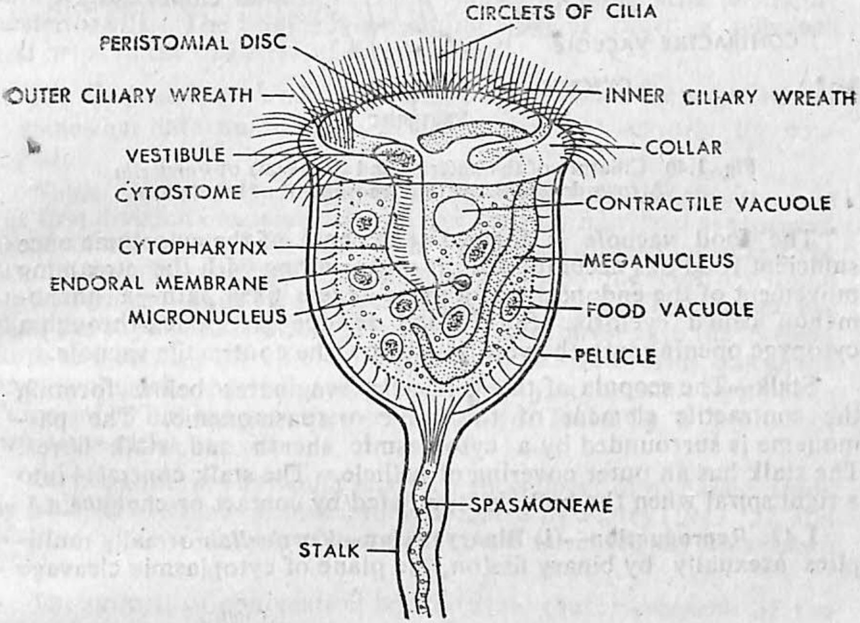


Fig. 1.39. Structure of *Vorticella*

The food current is channelled between the outer and inner whorls of cilia in the vestibule. Undesired particles are expelled or rejected along the path between the inner whorl and margin of the infundibulum.

The cytoplasm is differentiated into a thin outer ectoplasm surrounding a granular and fluid endoplasm. The body is covered with a pellicle. A single **contractile vacuole** is located near the vestibule. It empties its fluid into the vestibule from where it is passed out along the rejection current.

The **meganucleus** is large and bent in a horse-shoe shape. It is a **polyploid nucleus** containing DNA manifold of the DNA content of the small **micronucleus** situated close to it. The meganucleus is compact, granular controlling vegetative functions, while the micronucleus is vesicular concerned primarily with reproduction.

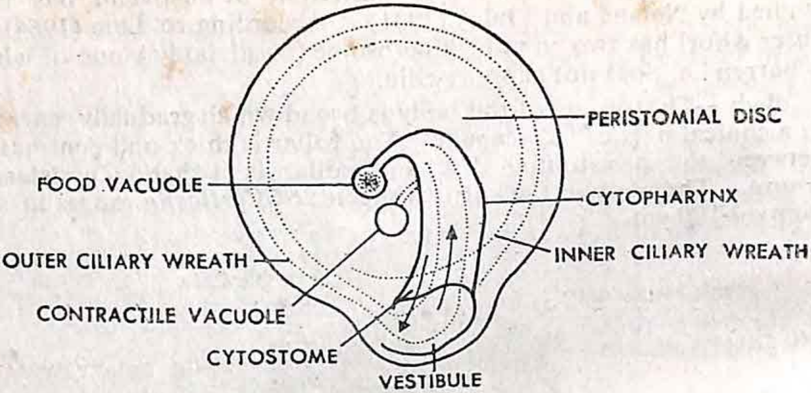


Fig. 1.40. Ciliature of the anterior end (free end) of *Vorticella* Arrows denote the path of movement of substances

The food vacuole is formed at the base of the cytostome once sufficient food has accumulated. It moves along with the streaming movement of the endoplasm in a more or less fixed path—a phenomenon called cyclosis. Solid food residue is egested through a cytopyge opening into the vestibule below the contractile vacuole.

Stalk—The scopula of the **Vorticella** evaginates below forming the contractile element of the stalk or spasmoneme. The spasmoneme is surrounded by a cytoplasmic sheath and stalk fibres. The stalk has an outer covering of pellicle. The stalk contracts into a tight spiral when the body is stimulated by contact or chemicals.

1.47. Reproduction—(i) Binary fission—*Vorticella* normally multiplies asexually by binary fission, the plane of cytoplasmic cleavage

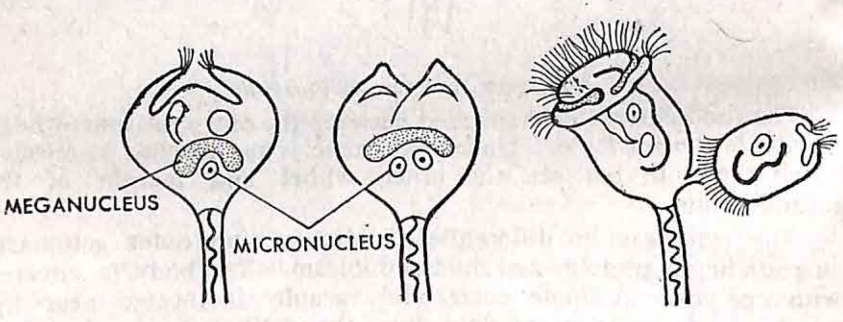


Fig. 1.41. Binary fission in *Vorticella*

being slightly obliquely longitudinal. The steps in binary fission are:

(i) Peristomial collar contracts and closes over the disc.

(ii) Macronucleus condenses to a sphere and divides directly.

(iii) A spindle of microtubules is formed which stretches between the opposite ends of the elongating micronuclear membrane.

(iv) Micro-nucleus divides by mitosis.

(v) Cytoplasm divides with the cleavage beginning at the centre of the peristomial disc to just one side of the stalk. Binary fission is completed in about 30 minutes.

Two daughter individuals, one slightly larger than the other retain the stalk. The other daughter develops a posterior circlet of cilia, swims for a while. develops a stalk and settles down after losing the posterior cilia. The brief free-swimming stage is called a **telotroch** and helps in the dispersal of the species.

(ii) Conjugation—Under certain conditions when the environment is somewhat unfavourable, *Vorticella* reproduces sexually by conjugation.

Some Vorticellids divide twice by repeated binary fission. At the first division one telotroch and one stalked individual are formed. Both divide again; the telotroch produces two telotrochs and the stalked daughter individual by division produces one telotroch and a stalked form. Thus three telotrochs are produced. They are smaller than the vegetative telotroch, do not metamorphose into the stalked form and become the microconjugant. The stalked forms acts as the megaconjugant. So the conjugants are not just the adult forms as in *Paramecium* but are produced from the adult forms by a process of two consecutive divisions.

Conjugation in *Vorticella* has been the subject of a classic study by **Maupas** (1899). It has been reinvestigated by **Finley** (1943, '52) and **Mugge** (1957). The phenomenon has been reviewed by **Sonneborn** (1957).

The process of conjugation begins with the attachment of the free-swimming microconjugant to the stalked megaconjugant near the posterior third of the body of the latter. If the microconjugant is unable to attach to a microconjugant within 24 hours of its formation it perishes.

In the microconjugant the micronucleus divides thrice. The last division is reductional. Out of the eight nuclei produced, seven degenerate, only one remains. This nucleus divides once producing two nuclei, one being the stationary pronucleus and the other a motile pronucleus. The meganucleus disintegrates and is absorbed in the cytoplasm of the microconjugant.

In the megaconjugant the micronucleus divides twice with the last division being reductional. Out of the four nuclei produced three are absorbed in the cytoplasm of the megaconjugant. The sole remaining nucleus divides into a motile pronucleus and a stationary pronucleus. The meganucleus disintegrates within the cytoplasm of the megaconjugant.

The two conjugants now become confluent with the disappearance of the partition wall. The wandering motile pronucleus of the microgamete migrates into the megaconjugant to fuse with its stationary pronucleus forming a synkaryon. The other two pronuclei degenerate. Part of the cytoplasm of the microconjugant also enters the megaconjugant, the former thus shrinks considerably, shrivels up and detaches.

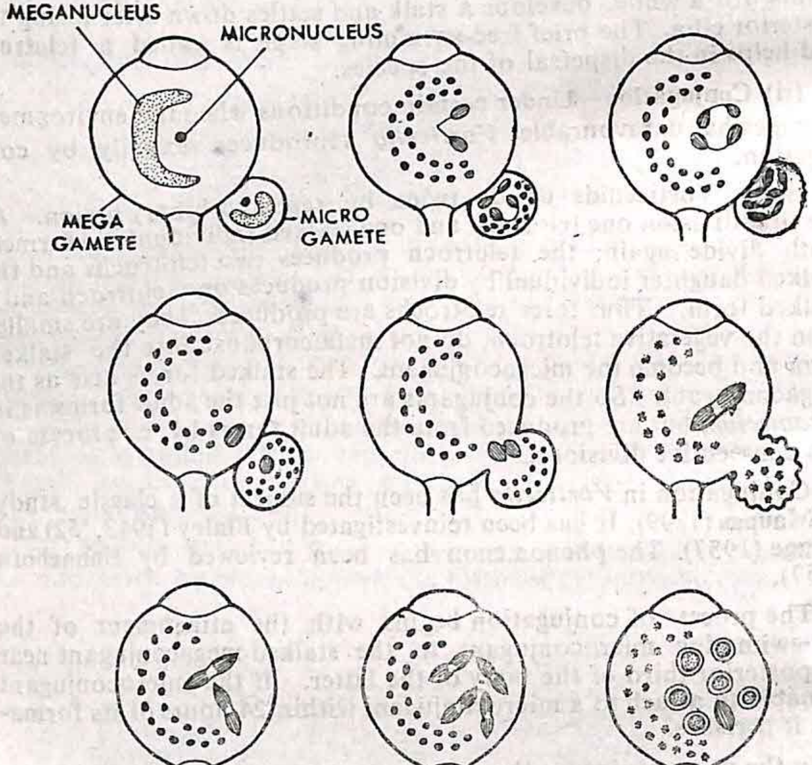


Fig. 1.42. Stages in Conjugation in *Vorticella* (Diagrammatic)

According to **Finley** (1952) the synkaryon in the megaconjugant divides thrice producing eight nuclei. Seven of these transform into meganucleus and the remaining one becomes a micronucleus. The seven meganuclei of the exconjugant are apportioned during its division to the seven daughter vorticellae. The micronucleus divides thrice in such a way that only seven micronuclei are produced and each daughter **Vorticella** gets one of them. Thus, as a result of conjugation seven young vorticellids are produced by the sole functional exconjugant.

1.48. Encystment—Under adverse conditions the adult individual converts itself into a telotroch by losing the stalk and developing a posterior circlet of cilia. It secretes a cyst wall and loses its cilia. Unfavourable environmental conditions are passed in the encysted condition. On return of favourable situation the animal emerges out of its cyst as a telotroch, swims a while, develops a stalk in place of cilia and settles down. Encystment is both a means to surmount unfavourable conditions and for the dispersal of the species.

1.49. Comparison of conjugation between *Vorticella* and *Paramecium*.

Vorticella	*Paramecium*
1. There is an incipient differentiation of sex among the conjugants. The conjugants are dissimilar in structure and behaviour. The microconjugant behaves like a male gamete and the megaconjugant as a female.	1. There is no indication of differentiation of sex. The conjugants are similar in form and behaviour. The conjugants can be looked upon as incipiently hermaphrodite.
2. The conjugants behave as gametes.	2. The conjugants do not act as true gametes.
3. The conjugants are formed by division and change in the fully-grown individuals.	3. The conjugants are indistinguishable from a fully-grown individual.
4. The conjugants attach themselves asymmetrically.	4. The conjugants adhere to one another symmetrically by their oral surfaces.
5. The micronucleus of the microconjugants divides forming 8 nuclei, that of megaconjugant forming only 4 nuclei.	5. The micronucleus in each conjugant divides forming 4 nuclei.
6. Seven nuclei of the microconjugant and three of the megaconjugant disappear in the cytoplasm. The remaining nuclei are spindle-shaped.	6. Three nuclei in each conjugant degenerate. The only remaining nucleus is oval or spherical in shape.
7. The pronucleus from the microgamete passes into the megagamete and fuses with its pronucleus. The two remaining nuclei one in each conjugant degenerate.	7. There is a reciprocal movement of the mobile pronuclei, each of which fuses reciprocally with the stationary pronucleus.

Vorticella	*Paramecium*
8. A single synkaryon within the megagamete only is formed.	8. Two synkarya, one each in the two conjugants, are formed.
9. Some cytoplasmic fusion between the two conjugants also occurs.	9. There is no cytoplasmic fusion between the gametes.
10. There is complete union of conjugants behaving as gametes.	10. There is a temporary coming together of the conjugants which separate after exchanging pronuclei.
11. Seven daughter individuals are formed consequent to conjugation.	11. Eight daughter individuals are formed after conjugation.
12. Conjugation approaches anisogamous syngamy.	12. Conjugation is not related in any way to syngamy.
13. No aberrant forms of conjugation are known.	13. Some aberrant forms of conjugation like autogamy and endomixis are also found.
14. No mating types have been discovered so far.	14. Conjugation occurs between the mating types of the different varieties or syngen.

The process of conjugation in *Vorticella* shows a marked advancement over that of *Paramecium.* Conjugation in *Vorticella* approaches anisogomous syngamy. The conjugants are formed and differentiated out of the adult *Vorticella* whereas in *Paramecium* the adult form directly transforms into a conjugant and is not different from the trophic form. The conjugants in *Vorticella* have structurally and functionally evolved in the direction of male and female **gametes.**

PARAMECIUM

Paramecium is an example of holotrichous ciliate which can be readily cultured and used for type study of a protozoan with one of the most complex structures.

1.50. Habit & Habitat—*Paramecium* is found in fresh water ponds, ditches, streams and water pools with fair amount of organic content present in the medium. The water in which paramecia are found is not stagnant. The ciliate habitually feeds on bacteria which are abundantly present in its habitat. *Paramecium* is a **mesosaprobe.**

1.51. Structure—*Paramecium* is an elgonated slipper-shaped or cigar-shaped ciliate just visible to the naked eye. The anterior end is rounded, the posterior is broad and conical. The body can be distinguished into a ventral flat or concave oral surface and a dorsal convex aboral surface.

Pellicle—The body is covered by a thin, firm, elastic pellicle which gives a definite body form to the organism. The surface of the body can be distinguished into a large number of hexagonal patterns surrounded by prominent ridges. A cilium emerges from the centre of each hexagonal depression. In the depression below the pellicles are cavities or **alveoli**. At the anterior and posterior margins of the depression in the middle of the arm of the hexagon are openings of the **trichocyst.**

Cilia—The entire body is covered with cilia of almost uniform length except those at the posterior end which are longer and called caudal tuft.

A cilium is an extension of the ectoplasm clothed with membranous sheath which is actually external outgrowth of the pellicle. In the matrix formed of ectoplasm nine longitudinal fibres peripherally disposed and two longitudinal fibres centrally placed are found. Each peripheral fibre is composed of two adhering subfibres or microtubules, one of which is provided with a pair of arms all disposed in the same direction. The central fibres are composed of two independent microtubles surrounded by a thin inner

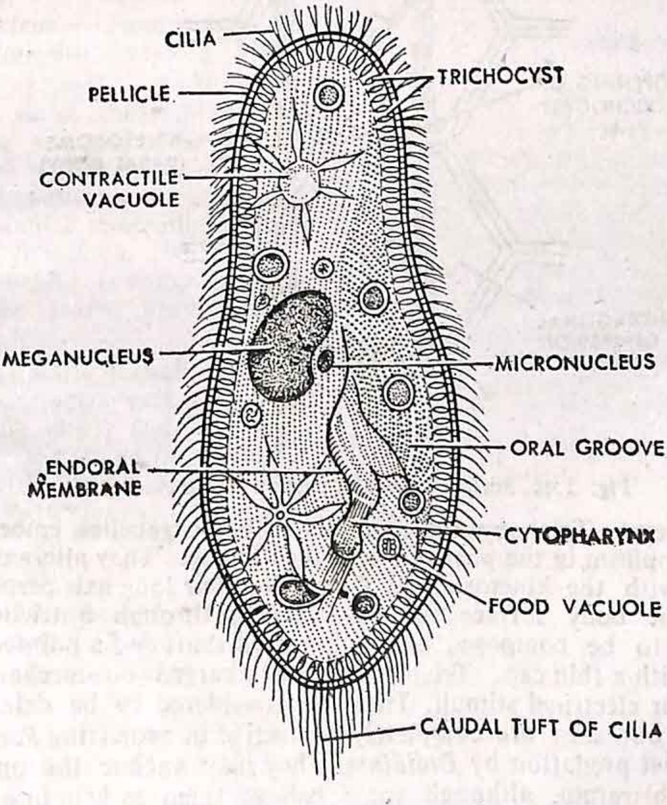


Fig. 1.43. *Paramecium caudatum*

membranous **sheath.** Nine radially directed fibres are disposed between the peripheral fibres and the inner sheath like spokes of a wheel. The peripheral fibres are continued below into the basal body or **kinetosome.**

From the kinetosome a fibril called **kinetodesmos** originates. It tapers toward anterior direction along its course. It joins similar kinetodesma from the posteriorily placed kinetosomes. Each kinetodesmos runs anteriorily ending after the fifth kinetosome.

The kinetosomes and kinetodesma constitute an infraciliary apparatus called **kinety.** The kineties with their cilia constitute the **neurolocomotor organelle.** The kineties control and coordinate the beating of the cilia.

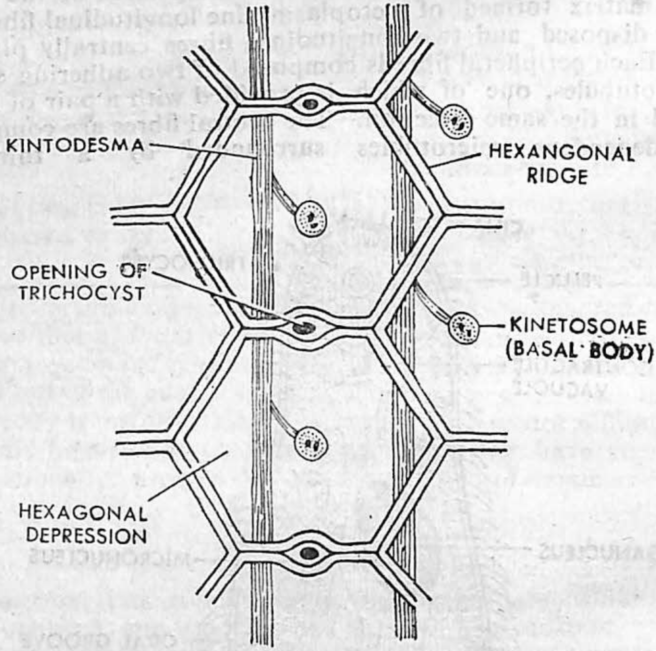


Fig. 1.44. Surface view of a portion of *Paramecium*

Trichocyst—Trichocysts are spindle-shaped organelles embedded in the ectoplasm in the position described above. They alternate in position with the kinetosomes. They have their long axis perpendicular to the body surface. A cross section through a trichocyst shows it to be composed of an elongated shaft end a pointed tip covered with a thin cap. Trichoysts are discharged on mechanical, chemical or electrical stimuli. They are considered to be defensive organelle but they are completely ineffective in protecting *Paramecium* against predation by *Didinium.* They may anchor the animal to the substratum, although some believe them to help in osmoregulation.

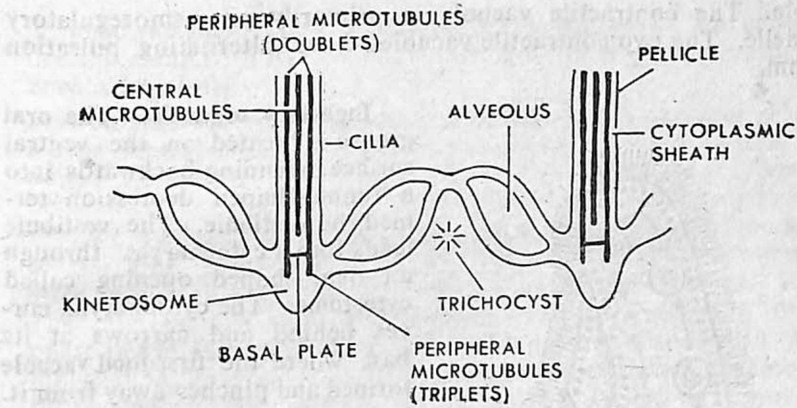


Fig. 1.45. Vertical Section through the surface of *Paramecium* showing position of Cilia, Kinetosome and Trichocyst

The cytoplasm of *Paramecium* is distinguishable into (a) an outer peripheral thin **cortex** or **ectoplasm** (b) an inner large **medulla or endoplasm.**

Nucleus — *Paramecium* is **heterokaryotic** with a large kidney-shaped meganucleus and a small shperical micronucleus situated close to the concave border of the former. The meganucleus is compact and granular controlling vegetative functions, while the micronucleus is vesicular responsible for reproduction only.

Contractile vacuole — Two large contractile vacuoles, one near the either end, lie close to the dorsal surface. Each contractile vacuole is surrounded by 6-10 elongated feeding canals. Each feeding canal consists of

(a) terminal part,

(b) ampulla, and

(c) injector canal which opens into the contractile vacuole. The filling in phase or diastole takes about 10 seconds in *P. caudatum*. When the vacuole is full it contracts and empties its content outside. This phase is called

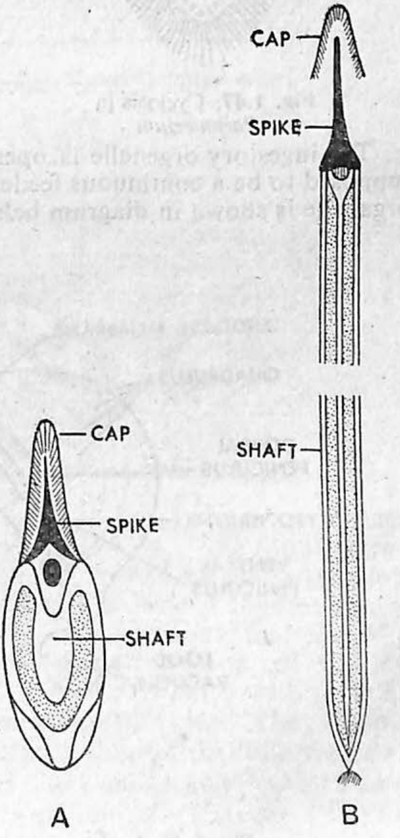


Fig. 1.46. Trichocyst : A—Undischarged, B—Discharged

systole. The contractile vacuole is primarily an osmoregulatory organelle. The two contractile vacuoles have alternating pulsation rhythm.

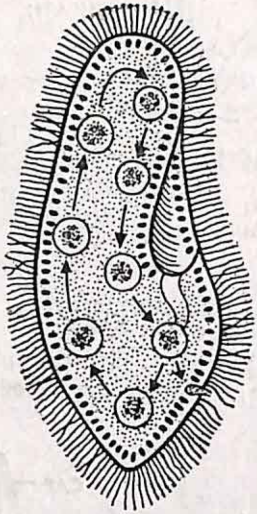


Fig. 1.47. Cyclosis in *Paramecium*

Ingestory organelle—The **oral groove** is located on the ventral surface extending backwards into a funnel-shaped depression termed the **vestibule**. The vestibule leads into a **cytopharynx** through an oval shaped opening called **cytostome.** The cytopharynx curves behind and narrows at its base where the first **food vacuole** formed and pinches away from it.

Just behind the cytostome cilia are fused to form a crescentic **endoral membrane.** The ciliation within the cytopharynx is localised from right to left into :

(a) Quadrulus,

(b) Dorsal peniculus, and

(c) Ventral peniculus.

Each of these consists of four rows of cilia.

The ingestory orgenelle is open throughout and *Paramecium* is supposed to be a continuous feeder. The ciliature of the ingestory organelle is shown in diagram below :.

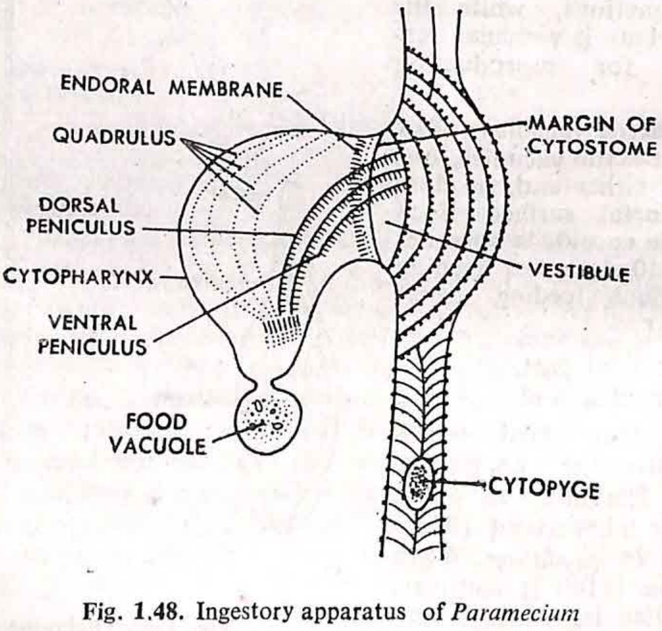


Fig. 1.48. Ingestory apparatus of *Paramecium*

Food vacuoles—These are found in fair number in the endoplasm moving along with its streaming movement in a regular path. This is called **cyclosis.**

Cytopyge—A spot for egestion of undigested particles is located on the ventral surface a short distance behind the cytostome.

Biology

1.52. Locomotion—*Paramecium* swims rapidly by the beating of the cilia. The cilia in a particular longitudinal row beat one after another in a succession in what is called **metachronal rhythm.** The cilia on the transverse location beat all together in the same phase in **synchronous rhythm.** The cilia are not disposed in perfect longitudinal lines but are slightly obliquely distributed. Consequently the animal rotates spirally on its axis to the left as it moves forwards. *Paramecium* can pass through narrow path by contracting and twisting its body.

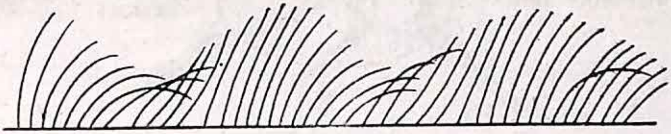


Fig. 1.49. (a) Metachronal rhythm in ciliary beats

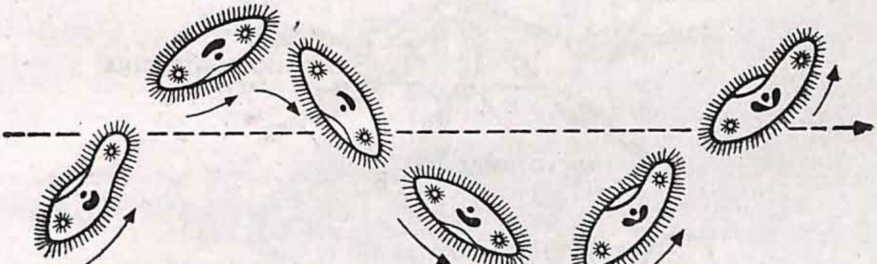


Fig. 1.49. (b) Path of locomotion in *Paramecium*

1.53. Nutrition—*Paramecium* is holozoic. It feeds on bacteria, algae, diatoms and other smaller protozoa. The food enters the cytostome along with the water current created by the lashing movement of the cilia on the oral groove. The food is concentrated into a ball or bolus by the coordinated movement of the cilia of the quadrulus and peniculus leading to the narrow end of the cytopharynx and surrounded in a food vacuole along with some fluid. The food vacuole pinches away and descends into the endoplasm free from the cytopharynx. The formation of the food vacuole is a continuous process and as soon as one food vacuole detaches another starts forming. *P. bursaria* has symbiotic *Zoochlorella*. It gets its carbohydrate requirement from the algae it harbours is an example of **heteroautotrophic** nutrition.

Digestive enzymes aggregate around the food vacuole in minute **lysosomes** which fuse with the vacuole delivering their enzymatic content. The initial reaction in the food vacuole is acidic during which most of the digestion occurs. Later the vacuole turns alkaline. The digested food is absorbed into the adjacent cytoplasm during the cyclosis of the food vacuole. Undigested residue in the food vacuole is egested through the cytopyge.

1.54. Respiration—Exchange of gases between the animal and the ambient water takes place across the body surface by diffusion.

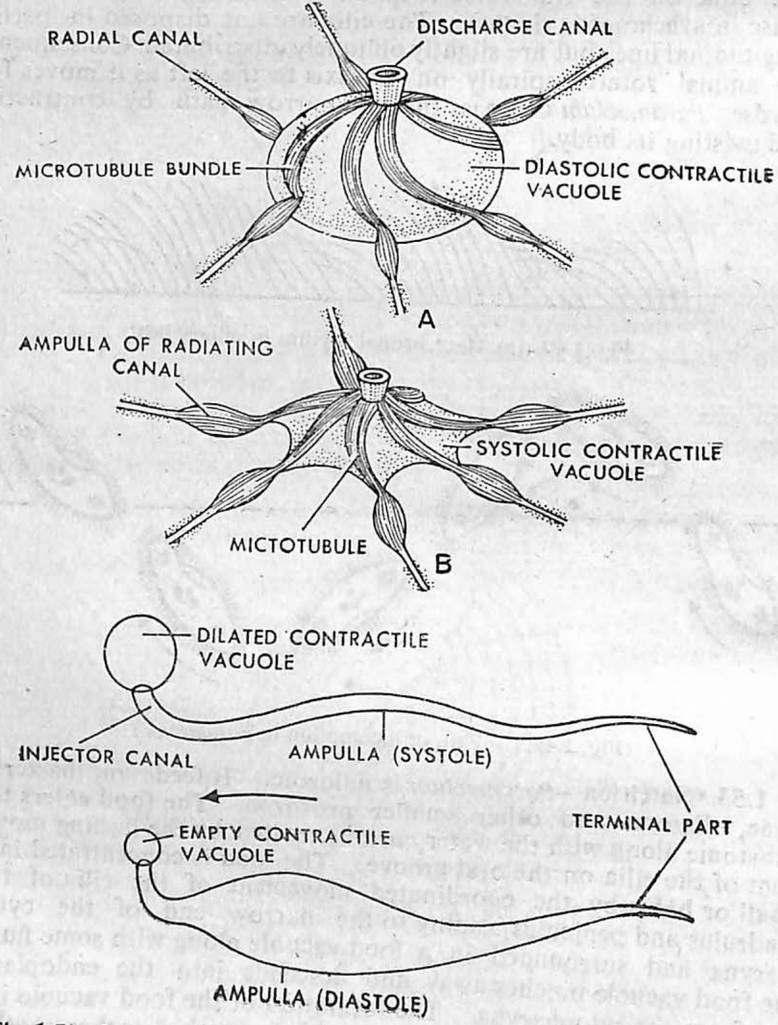

RADIAL CANAL
DISCHARGE CANAL
MICROTUBULE BUNDLE
DIASTOLIC CONTRACTILE VACUOLE
A
AMPULLA OF RADIATING CANAL
SYSTOLIC CONTRACTILE VACUOLE
MICTOTUBULE
B
DILATED CONTRACTILE VACUOLE
INJECTOR CANAL
AMPULLA (SYSTOLE)
TERMINAL PART
EMPTY CONTRACTILE VACUOLE
AMPULLA (DIASTOLE)

Fig. 1.50. Osmoregulatory organelle of *Paramecium*. A—During Diastole, B—During Systole. Details of feeder canal given at the bottom of the diagram

1.55. Excretion—Nitrogenous wastes like urea, NH_3 etc. are also removed by the general body surface by diffusion. The cytoplasm often accumulates excretory crystals of calcium phosphate.

1.56. Reproduction—*Paramecium* reproduces both asexually and sexually.

(i) Asexual reproduction—This is the more common mode of reproduction and occurs uninterruptedly until the environmental factors become adverse and the density of population of the ciliate increases considerably. The animal stops feeding at the onset of asexual reproduction which takes place by **transverse binary fission.**

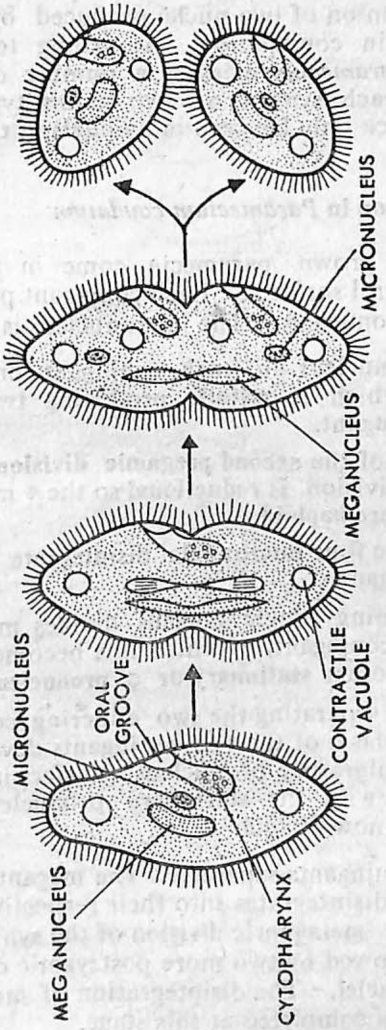


Fig. 1.51. Binary fission in *Paramecium* (Diagrammatic)

The micronucleus divides into two by mitosis. The nuclear membrane however remains intact during the division. The meganucleus elongates and pinches in the middle dividing amitotically into two. The nuclei move towards opposite ends of the animal and simultaneously a constriction appears in the middle of the body dividing it into two paramecia. The binary fission involves complex changes in the ciliary system and other organelles. The parental oral groove, vestibule and cytopharynx go to one daughter individual and a new set of these structures is differentiated in the other daughter before division is completed. Binary fission takes 30-120 minutes to complete.

(ii) Sexual reproduction—Sexual activity in *Paramecium* involves a special form of union of two nuclei produced by two individuals coming together in conjugation. According to **Sonneborn** (1957) many species of *Paramecium* exist in a number of varieties called **syngen**. Within each syngen are two **mating** types. Conjugation normally takes place only between individuals of the mating type of the same syngen.

1.57. Conjugation in *Paramecium caudatum*

(i) Two fully grown paramecia come in pairs as **conjugants** attached by their oral surfaces. Each conjugant possesses a mega-, nucleus and a micronucleus. The micronucleus is **diploid**.

(ii) The micronucleus in each conjugant undergoes the **first pregamic division** which is **mitotic** producing two diploid micronuclei in each conjugant.

(iii) As a result of the **second pregamic division** four nuclei are produced. This division is **reductional** so the 4 micronuclei carried by each conjugant are **haploid**.

(vi) Three of the four micronuclei disintegrate within the cytoplasm of the conjugant.

(v) The remaining single nucleus divides mitotically into two pronuclei in each conjugant, of which one becomes **migratory** or ♂ **pronucleus** and the other **stationary** or ♀ **pronucleus**.

(vi) The pellicle separating the two adhering conjugants disintegrate and the cytoplasm of the two conjugants develops a bridge between them. Each migratory pronucleus transfers into the other conjugant and fuses with the stationary pronucleus to produce a **synkaryon** which is now **diploid**.

(vii) The two conjugants separate. The meganucleus in the now called **exconjugants** disintegrates into their respective cytoplasm. The first **postzygotic** or **metagamic division** of the synkaryon yields two nuclei. This is followed by two more postzygotic divisions resulting in eight daughter nuclei. The disintegration of meganucleus which sets in much early is completed at this stage.

(viii) Three of these nuclei (all diploid because **postzygotic divisions are mitotic**) disintegrate into the cytoplasm of the respective exconjugant.

(ix) Out of the five remaining nuclei—one transforms into a micronucleus and the rest four become meganuclei.

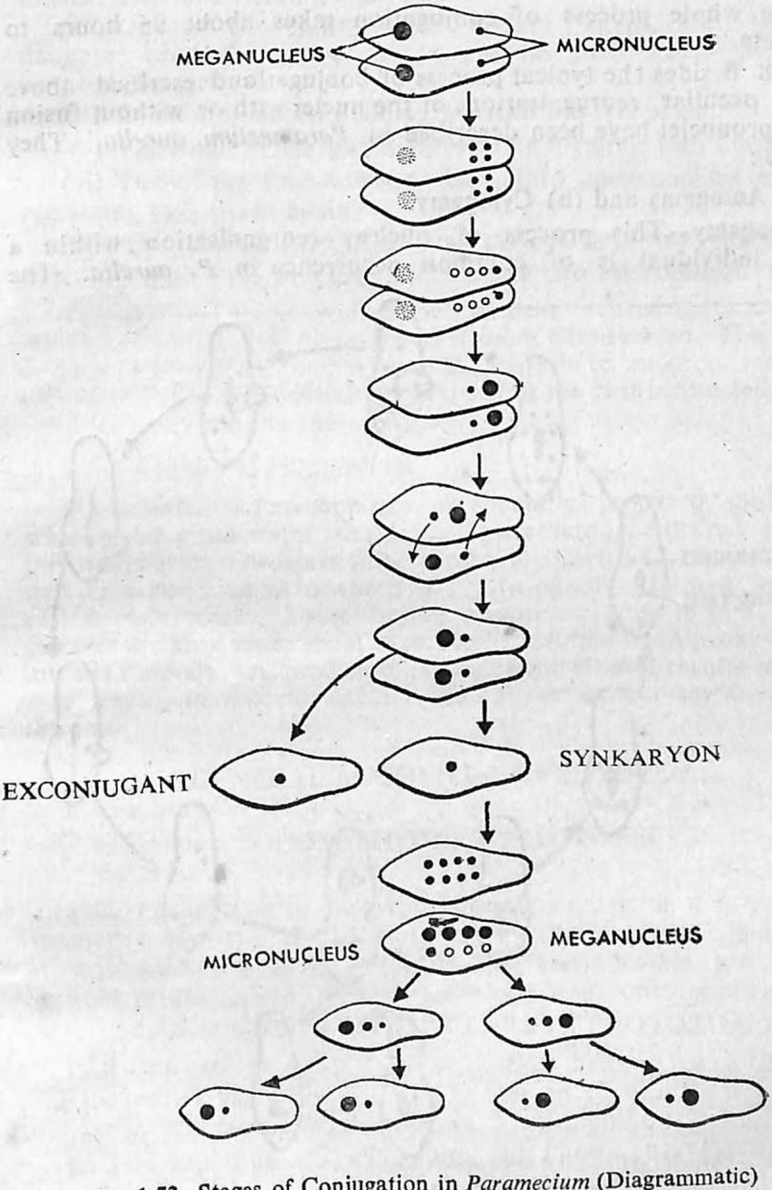


Fig. 1.52. Stages of Conjugation in *Paramecium* (Diagrammatic)

(x) In two successive cell divisions the four meganuclei are distributed or apportioned to four daughter individuals. The micronucleus divides once with each cell division.

(xi) The result of all these is the production of 4 daughter paramecia each with one meganucleus and a micronucleus from each exconjugant.

The whole process of conjugation takes about 96 hours to complete.

1.58. Besides the typical process of conjugationd escribed above a few peculiar reorganisations of the nuclei with or without fusion of the pronuclei have been described in *Paramecium aurelia*. They include :

(a) **Autogamy** and (b) **Cytogamy.**

Autogamy—This process of nuclear reorganisation within a single individual is of common occurrence in *P. aurelia*. The

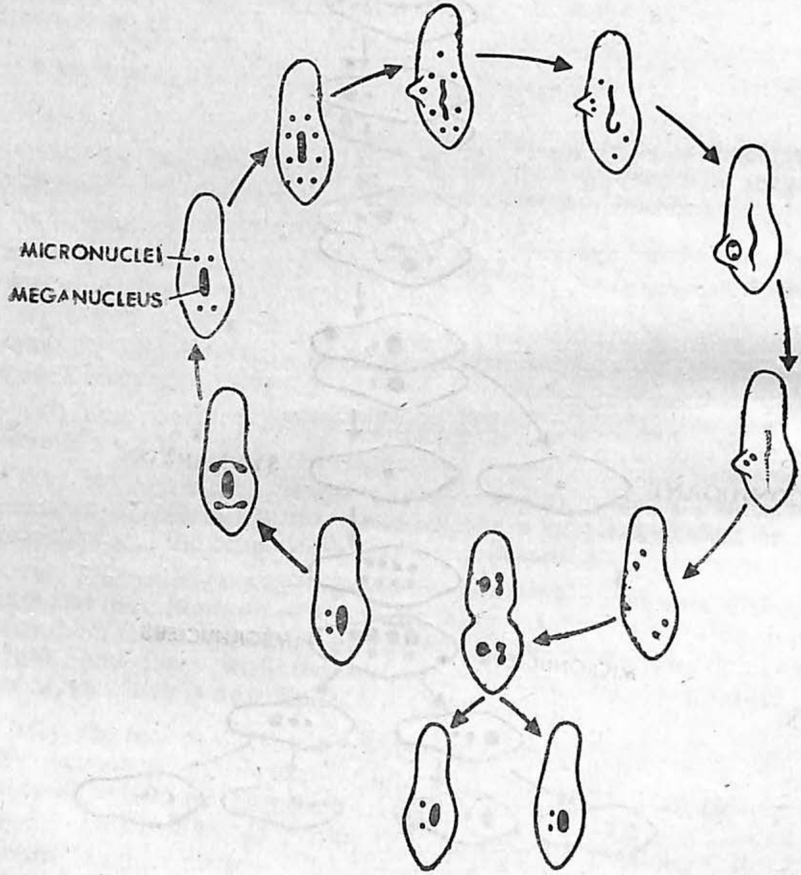


Fig. 1.53. Autogamy in *P. aurelia*

nuclear changes resemble those in typical conjugation. The process takes place in the following steps :

(i) The meganucleus ramifies and disintegrates into the cytoplasm.

(ii) The two micronuclei of the individual divide by two repeated nuclear divisions yielding eight nuclei.

(iii) One of the eight nuclei divides again, and the two daughter pronuclei move into a paroral cone where they fuse between themselves.

(iv) Remaining nuclei disintegrate into the cytoplasm.

(v) The single synkaryon divides twice forming four nuclei.

(vi) Two of the four nuclei develop into meganucleus and the remaining two divide again.

(vii) Cytoplasm of the individual divides into two yielding two *P. aurelia* each with one meganucleus and two micronuclei.

Cytogamy—This is a form of nuclear reorganisation during which two individuals come together as in conjugation. The nucleus undergoes changes as in conjugation but fails to make a reciprocal exchange. The individuals separate after the two pronuclei of each conjugant fuse among themselves.

1.59. Culture of *Paramecium*

P. caudatum often appears in specially prepared medium in which some pond water is added. This ciliate is cultured in glass jars with covers which are filled three-fourth with Chalkey's medium or boiled pond water to which 7-12 drops of skimmed milk are added each week. Some boiled hay or wheat grain is added and the jars are kept away from direct light. Some fresh pond water is infused (added). A good population of the ciliates results in about 7-15 days. *Paramecia* usually are found near the surface scum in the jars.

GENERAL ACCOUNT OF PROTOZOA

LOCOMOTION IN PROTOZOA

1.60. Locomotion in protozoa includes a study of the locomotor organelles and the mechanisms by which movement is achieved. Most protozoa are motile but a few like the suctoria are fixed to the substratum and on other animals by a non-contractile stalk.

LOCOMOTOR ORGANELLES IN PROTOZOA

Protozoa possess a variety of organelles helping in locomotion. The locomotor organelles are closely associated with the body surface and are largely ectoplasmic in origin. They include :

(i) Pseudopodium, (ii) Flagellum, (iii) Cilium, (iv) 'Myoneme'.

The types and occurrence of the locomotory organelle are used as important taxonomic index in classifying the phylum Protozoa.

A. **Pseudopodium**—Pseudopodia are temporary cytoplasmic extensions of the body surface. They are found in nonpelliculate forms, can be withdrawn quickly and formed afresh rapidly depending on the activity of the animal.

Pseudopodia are of two main types :

(a) **Axopodia** or actinopodia in which the cytoplasmic process is internally stiffened.

(b) **Rhizopodia** which are devoid of stiffeners.

Rhizopodia are divisible into :

(i) **Lobopodia,**
(ii) **Filopodia,**
(iii) **Reticulopodia.**

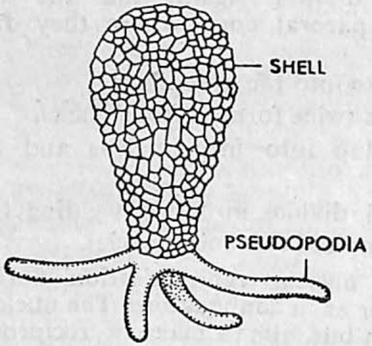


Fig. 1.54. Lobopodia in *Difflugia*

Lobopodia are characteristic of amoeboid protozoans. They are broad finger-like or lobe-like projection of both the ectoplasm and endoplasm. The ectoplasmic component is in a state of gel while the endoplasm is sol. The advancing pseudopodium is tipped by a **hyaline cap.** Lobopod in *Entamoeba histolytica* is completely ectoplasmic.

Filopodia are slender and filamentous formed exclusively of ectoplasm having a pointed tip. They branch but the branches do not reunite (See Fig. 1.2). Filopodia are found in *Euglypha* and other testaceans.

Reticulopodia are similar to filopodia but always branch and the branches anastomose with one another forming numerous reticula. These are found in foraminifera.

Axopodia are semi-permanent structures radiating out from the centre. Each axopodium is strengthened by an internal **axial filament** consisting of a number of fibrils. The axial filament usually originates from a central granule in the middle of the protozoan body, sometimes within the nucleus (See Fig. 1.4.).

The axopodia largely serves as structures for floating passively on the water surface and for food capture. They are used for locomotion only when the protozoan is in contact with substratum. The axial filament consists of a number of microtubules.

B. Flagellum—Flagella are very fine, filamentous, highly vibratile extensions of the cytoplasm characteristic of Mastigophora. Each flagellum consists of a central axoneme composed of 2+9 sets of microtubules continued basally with a basal granule or blepharoplast. The axoneme is ensheathed in an extension of cytoplasm.

Pitelka (1949) studied the ultrastructure of flagella of *Euglena gracilis* and its colourless relative *Astasia longa*. The axoneme consists of 2 central and 9 peripheral sets of microtubules, each measuring 350-600Å units in diameter. Both the components, the axoneme and cytoplasmic sheath, may extend the whole length of the flagellum or the axoneme may be left naked to various degrees. In many flagella lateral filaments arising out of one, two or more of the peripheral fibrils may be found. They are called **mastigonemes**. In mastigophorans possessing a trailing flagellum besides a leading one, the former is devoid of mastigonemes.

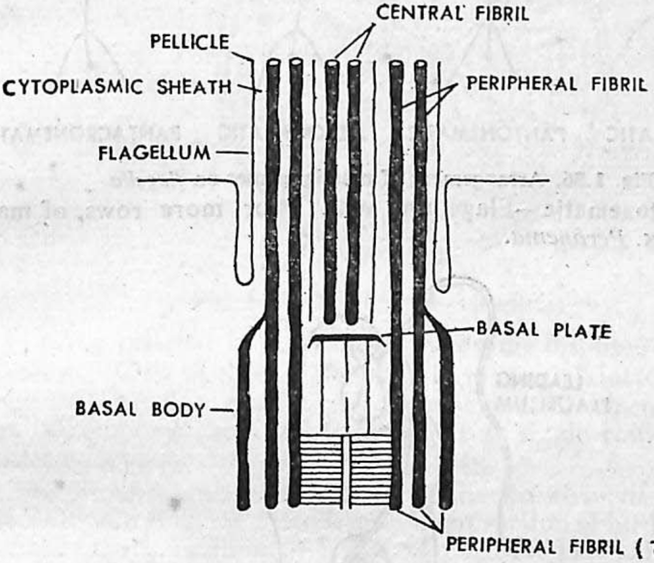


Fig. 1.55. L. S. of flagellum with basal body—Ultrastructure

Flagella are divided into the following types on the basis of presence and absence as well as distribution of the mastigonemes :

(i) **Stichonematic**—Flagella with only one row of mastigonemes disposed in the same side. Ex. *Euglena*.

(ii) **Pentacronematic**—Flagellum near the tip naked and provided with mastigonemes in two rows. Ex. *Monas*.

(iii) **Acronematic**—Flagellum with a terminal filament mastigonemes not present. Ex. *Polytoma*.

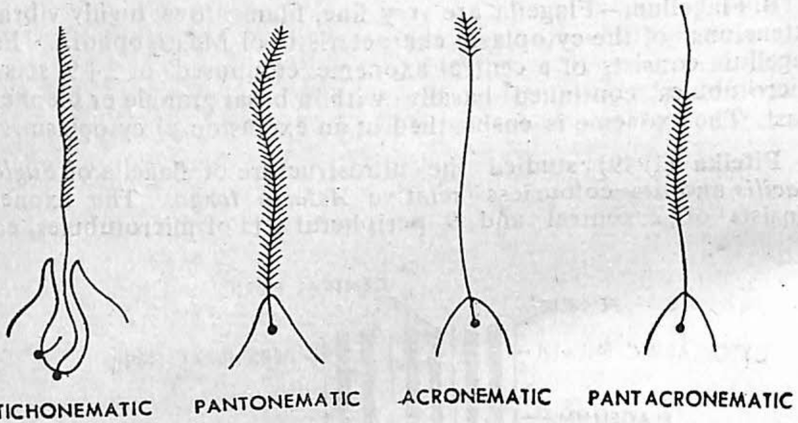


Fig. 1.56. Arrangement of mastigonemes on *flagella*

(iv) **Pantonematic**—Flagellum with 2 or more rows, of mastigoneme. **Ex.** *Peranema.*

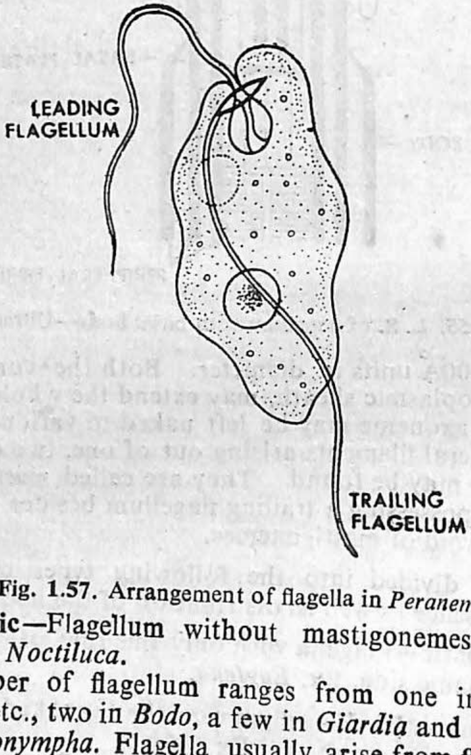


Fig. 1.57. Arrangement of flagella in *Peranema*

(v) **Anematic**—Flagellum without mastigonemes and terminal filament. Ex. *Noctiluca.*

(The number of flagellum ranges from one in *Copromonas, Trypanosoma* etc., two in *Bodo*, a few in *Giardia* and *Trichomonas* to many in *Trichonympha.* Flagella usually arise from **flagellar pockets or flagellar sacs.**)

C. **Cilium**—Cilia are extremely fine thin extensions of the ectoplasm. They are much shorter and more numerous than flagella.

They cover the entire body e.g., **Holotricha,** restricted to within a few circlets e.g., **Peritricha** or confined to the ventral surface e.g., **Hypotricha.** Cilia are arranged in longitudinal, oblique or spiral rows being inserted to individual kinetosome disposed on a ridge or a furrow. Cilia of a particular row have their kinetosomes interconnected by fine fibrils called neuroneme or **kinetodesma.** The cilia, kinetosomes, and kinetodesma of a single row constitute a functional neurolocomotor unit or **Kinety.**

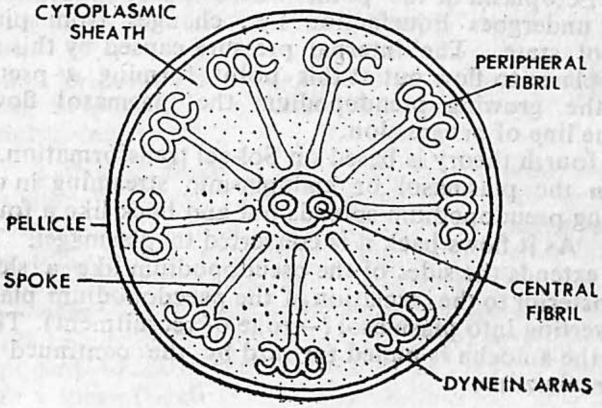


Fig. **1.58.** C. S. of cilia—ultrastructure

The ultrastructure of a cilium is similar to that of a flagellum. The ultrastructure of a cilium in cross section **(Fig. 1.58.)** is given by **Satir** (1968) and that of a flagellum by **Westphal** (1976).

In **hypotricha** cilia are largely replaced by **cirri.** *Stylonychia* literally crawls on its cirri.

D. Myonemes—On the surface of many sporozoa and flagellates spiral or oblique ridges are found each associated with one or a few contractile microtubules. When waves of contraction pass over the body from one end to the other the animal is able to creep slightly.

1.61. Mechanism of Locomotion in Protozoa

A. Amoeboid or pseudopodial movement—In Sarcodina a single or a few pseudopodia help in flowing locomotion of the animal with the pseudopodial tips maintaining contact with the substratum.

A number of theories have been proposed to explain the mechanism of pseudopodial locomotion. They are :

(i) **Surface tension theory of Rhumbler** (1898).

(ii) **Contraction theory** of **Dellinger** (1906).

(iii) **Change of viscosity** or **Sol-gel theory** of **Hyman (1917), Mast** (1923-25) and **Pantin** (1923).

(iv) **Front contraction theory** or **Fountain zone theory** of **Allen** (1961) and **Goldacre** (1961-64).

The earlier two theories are only of historical interest.

According to the **Sol-gel theory** cytoplasmic flow and pseudopodium formation result from changes in colloid state of the cytoplasm. Ectoplasm at the point where pseudopodium is to be formed undergoes liquefaction i.e., changes from plasmagel to plasmasol state. The internal pressure caused by this shift causes the cytoplasm to flow out at this point forming a pseudopodium. Inside the growing pseudopodium the plasmasol flows forward along the line of progression.

The fourth theory is based on Sol-gel transformation. According to **Allen** the plasmasol or endoplasmic streaming in centre of an advancing pseudopodium spreads out and back like a fountain near the tip. As it flows back it is converted to plasmagel. This builds up and extends the sides of the pseudopodium like a sleeve. At a point posterior to the formation of the pseudopodium plasmagel goes on converting into plasmasol (—zone of recruitment). The posterior part of the amoeba is pulled forward by the continued activity at the fountain zone.

According to **Goldacre** the plasmagel contracts at the rear end of the body and squeezes the plasmasol forward.

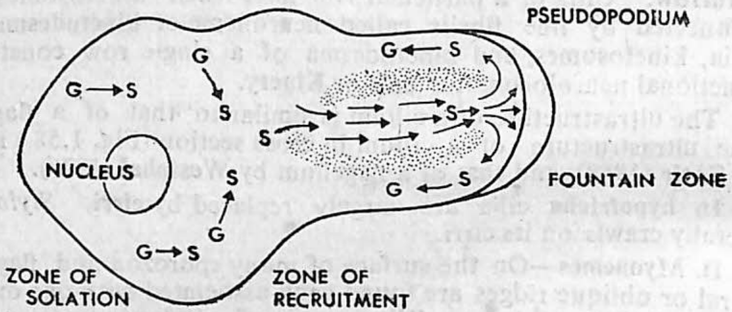


Fig. 1.59. Schematic diagram of pseudopodial formation

Recently both **actin, myosin,** thick and thin filaments have been recognised in *Amoeba*. According to **Huxley** (1973) amoeboid movement is due to the interactions of these microfilaments in a manner similar to that described for metazoan muscles. One filament glides on the other which is anchored in the gel region. This pulls the animal forward. The filaments are largely confined to the ectoplasm. Addition of ATP and Ca^{++} or Mg^{++} induces glycerinated amoeba to contract. According to **Giese** (1979) actin and myosin filamentar interactions cause locomotion in the mycetozoan *Physarum*.

B. Flagellar movement—According to **Butschlii** a flagellum undergoes a series of lateral movements during which pressure is exerted at right angles to its surface. This can be resolved into (a) a force parallel to the body and (b) a force at right angles to the main axis. The first drives the animal forward and the second rotates the animal on its axis. The animal is propelled like a screw.

Metzner (1920) however, thought that flagellum beats in a circle tracing a cone producing sufficient suction to drive the flagellate forward.

Ulhela and **Krijsman** (1925) suggested that a flagellum moves in sideway lash consisting of an effective bending stroke and a recovering straightening stroke.

The latest theory about flagellar movement suggests that a flagellum undergoes spiral undulations with the waves on it usually passing from base to the tip. The flagellum is usually held backward of the body during swimming. The lateral undulations are **sinusoidal** and the spiral undulations are **helicoidal**. Usually no sharp distinction between sinusoidal and helicoidal motions can be made. (See Fig. 1.28.) Helicoidal motion adds a **gyrational** (rotating on its axis) component to movement and the animal is propelled forward in water like a screw (**Grell** 1973). The locomotive force produced by a given flagellar wave form depends on the amplitude, wavelength and frequency of the movement of waves along the flagellar length. Mastigonemes increase the surface area of a flagellum and consequently its effectiveness also.

C. Ciliary locomotion—Each cilium acts as an oar. Each lash of a cilium consists of an effective stroke (E) and a recovery stroke (R) which occurs in one plane. During effective stroke the cilia move toward one side outstretched bending only at the base. In the recovery stroke the cilia are bent and in this state are returned to the starting position with least resistance from the water. During the effective stroke water strikes the cilia at right angles to its length, the animal moving in the direction opposite to it.

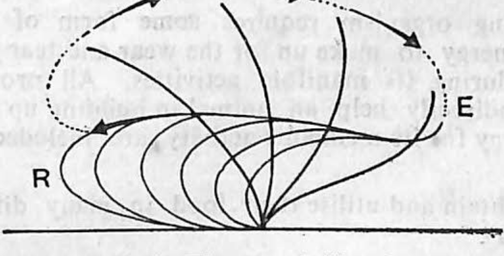


Fig. 1.60. Diagram of ciliary beat :
E—Effective Stroke; R—Recovery Stroke

Cilia are usually disposed in linear series. A cilium in a particular row beats slightly in advance of the cilium behind it and slightly later than the cilium just ahead of it. Thus the cilia on the same linear row are not in the same phase at any one time and are said to beat in a metachronous rhythm. On the other hand, cilia of the transverse row vibrate synchronously. The ciliates are the fastest protozoan.

The bending of both flagella and cilia is caused by contractions of their peripheral microtubules.

According to **Giese** (1979) ciliary movement is caused by the sliding of the members of a doublet of microtubules in relationship to one another by a ratchet-like mechanism. The sliding of peripheral doublets is resisted by the radial spokes which lead to the bending of the cilium.

Although cilia and flagella are essentially similar in structure the following may be used to distinguish between them :

(i) Cilia are much shorter and more numerous than flagella.

(ii) Cilia usually vibrate in a coordinated manner
—synchronous rhythm in transverse rows
—metachronous rhythm in longitudinal rows.

A flagellum moves in sinusoidal and helicoidal undulations independently of other members present in the protozoan.

(iii) A neuroneme or kinetodesma connects successive kinetosomes supporting cilia which control their vibration. When more than one flagellum is present their blepharoplasts are not united.

(iv) In a cilium no mastigoneme is present, whereas in a flagellum it is commonly found.

NUTRITION IN PROTOZOA

1.62. Nutrition in Protozoa

Every living organism requires some form of nourishment to provide energy to make up for the wear and tear of body components lost during its manifold activities. All processes which directly or indirectly help an animal in building up the body and providing energy for its metabolic activity are included within the term nutrition.

Protozoa obtain and utilise their food in many different ways. They are either :

(i) **Heterotrophic,** or

(ii) **Autotrophic** depending on whether they rely on other organisms for the nutritional requirements or synthesize their own food.

1.63. Heterotrophic Nutrition

Heterotrophs require many organic substances but the autotrophs use inorganic substances to synthesize organic products.

Heterotrophs are further classified into :

(a) Holozoic or zootrophic or phagotrophic
(b) Saprozoic
(c) Saprophytic, and
(d) Mixotrophic types.

(a) Holozoic nutrition—Majority of free-living protozoa utilise holozoic method. It is a complex method including a number of steps :

(i) ingestion including food capture and formation of food vacuole.

(ii) digestion including secretion of digestive enzymes into the food vacuole.

(iii) assimilation including absorption of digested food products from the food vacuole into adjacent cytoplasm.

(iv) egestion or removal of undigested food residue, and

(v) storage of surplus food as reserves.

Ingestion—The first step in holozoic nutrition is ingestion or engulfing of food. When live food organisms are used they have to be captured with the help of ingestory organelle.

In Sarcodina the food is captured, taken into the body and contained in food vacuole at any point on the body surface. Pseudopodia help in ingestion as these protozoans lack a permanent mouth or cytostome.

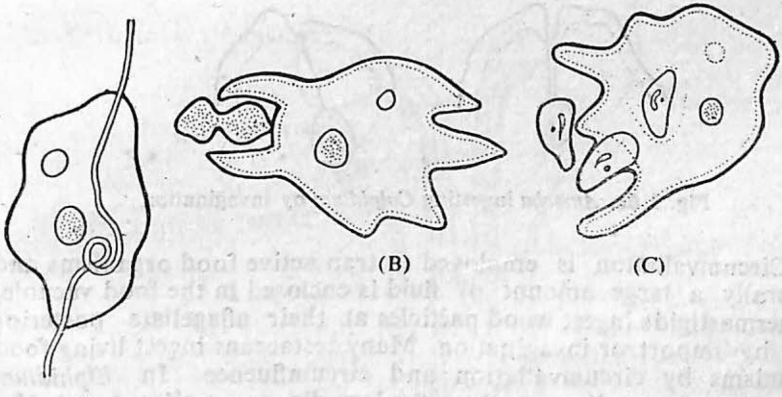


Fig. 1.61. A—*Amobea* ingesting *Oscillatoria* by import. B—*Amoeba* ingesting bacterial glea by circumfluence. C—*Amoeba* feeding on *Paramecium* by circumvallation

Rhumbler (1910) has described four methods of ingestion in amoeboid protozoa. They are:

(i) Import—Food is taken into the body upon contact with very little movement on the part of the animal, *Ex-Amoeba verrucosa* feeding on filamentous algae.

(ii) Circumfluence—The cytoplasm of the amoeba flows around the food organism as soon as it comes in contact with it on all sides by pseudopodial formation and engulfs it.

Ex. *Chaos diffluens* (= *Amoeba proteus*) feeding on bacterial glea.

(iii) Circumvallation—The protozoa without contact with the food organism forms pseudopodia which surrounds the food on all sides and ingests it.

Ex. Species of *Amoeba* feeding on *Paramecium.*

(iv) Invagination—The amoeboid protozoan adheres to food and the ectoplasm in contact with the food invaginate, into the endoplasm as a tube with the food vacuole forming at its base. Circumfluence is used in dealing with inert food and a relatively small amount of fluid is included with the food in the food vacuole. Some Heliozoans also use this method.

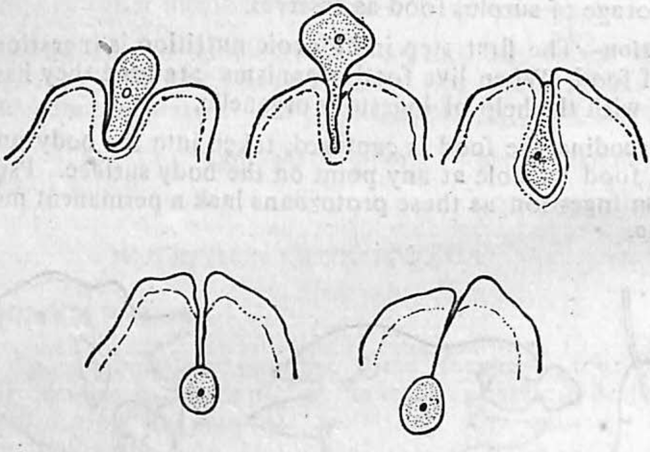


Fig. 1.62. *Amoeba* ingesting *Colpidium* by invagination

Circumvallation is employed to trap active food organisms and naturally a large amount of fluid is enclosed in the food vacuole. Hypermastigids ingest wood particles at their aflagellate posterior end by import or invagination. Many testaceans ingest living food organisms by circumvallation and circumfluence. In *Elphidium* living organisms adhere to the reticulopodia, are paralysed and then ingested in reticulum outside the shell. Electron micrograph of trophozoite of species of *Plasmodium* and *Babesia* show that these parasites engulf host cell cytoplasm in phagotrophic fashion.

Peranema traps *Euglena* by first harpooning the victim with its oral rods and then engulfing it. The aforesaid methods of ingestion are not confined to Sarcodina. Many astomatous (=lacking a cytostome) protozoans resort to these modes of ingestion.

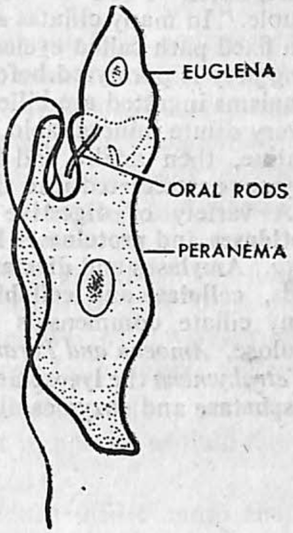


Fig. 1.63. *Peranema* feeding on *Euglena* by spearing the victim with its oral rods

In Suctoria the suctorial tentacles are used as ingestory organelle. The tips of these tentacles are devoid of pellicle and possess haptocysts which pierce into the body of the prey and grasp it. The tentacle then hollows in and the prey is sucked inside into the endoplasm and enclosed in food vacuole.

In the ciliates a variety of ingestory organelle, the cytostome with its specialised ciliature is used for obtaining food. In *Paramecium* the cytostome is a permanently open structure. It is a continuous feeder. In *Didinium* and *Coleps* the cytostome opens only when a prey is to be ingested. In raptorial ciliates like *Prorodon* a circlet of trichites surrounds the cytostome. In *Vorticella* peristomial ciliated tracts descend into the cytopharynx producing well-defined food selection and waste rejection currents.

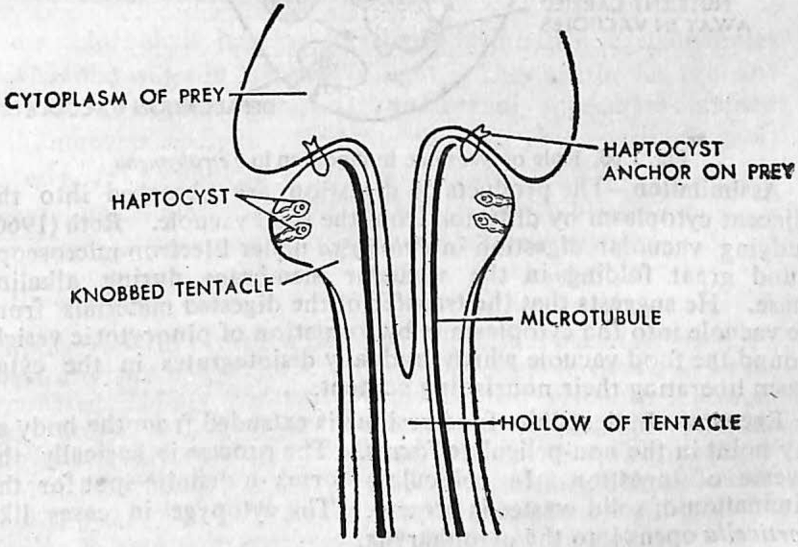


Fig. 1.64. Prey of a Suctorian individual being sucked in through the hollowed tentacle. The prey is anchored to the Suctorian with haptocysts

Digestion—Food is usually ingested with some fluid in a food vacuole. In many ciliates a definite movement of the food vacuole in a fixed path called **cyclosis** is seen. In foraminifera and suctoria living prey is paralysed before ingestion. In other forms the living organisms ingested are killed in the food vacuole usually by secretion of very dilute mineral acid. The food vacuole in many protozoa is alkaline, then acidic and finally alkaline (**Muller,** 1962). Digestive enzymes are secreted into the food vacuole as minute spherules.

A variety of digestive enzymes are secreted by the protozoa. **Peptidases** and **proteinases** have been reported from *Amoeba, Pelomyxa.* **Amylases** and **diastatic activity** have been found in hypermastigids, **cellulase** and **cellobiase** digest cellulose in hypermastigids. Many ciliate commensals in the stomach of ruminants can digest cellulose. *Amoeba and Peranema can digest* fats and oil **(Chen,** 1950). In *Tetrahymena* the **lysosomes** provide **glucosidases, proteases, amylase, phosphatase** and enzymes digesting nucleic acids.

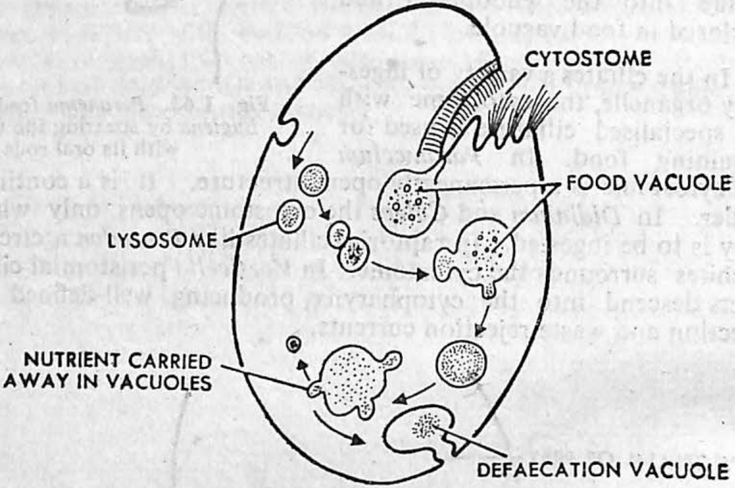


Fig. 1.65. Role of lysosome in digestion in *Tetrahymena*

Assimilation—The products of digestion are absorbed into the adjacent cytoplasm by diffusion from the food vacuole. **Roth (1960)** studying vacuolar digestion in *Pelomyxa* under Electron microscope found great foldings in the vacuolar membrane during alkaline phase. He suggests that the transfer of the digested materials from the vacuole into the cytoplasm is by formation of pinocytotic vesicle around the food vacuole which gradually disintegrates in the cytoplasm liberating their nourishing content.

Egestion—Indigestible food residue is extruded from the body at any point in the non-peliculate forms. The process is basically the reverse of ingestion. In pelliculate forms a definite spot for the elimination of solid wastes is present. The cytopyge in cases like *Vorticella* opens into the cytopharynx.

(b) Saprozoic nutrition—A number of protozoa live in media rich in assimilable food. They simply absorb the fluid nourishment by endosmosis and are therefore also called **osmotrophs**, in contrast to the holozoic forms which engulf solid food and hence termed **phagotroph.** Parasitic protozoa like *Trypanosoma, Balantidium, Opalina* etc. utilise this method. Saprozoic forms naturally do not normally possess ingestory organelles, food vacuoles and digestive enzymes are redundant.

(c) Saprophytic nutrition—Some protozoans absorb simple substances produced either by decay of organic material or by digestion by enzyme secreted by the protozoans themselves as in **Mycetozoa.** The distinction between saprozoic and saprophytic modes is not very clear. Both the processes are quite similar. Many protozoa ranging from *Amoeba* to *Plasmodium*, resort to uptake of fluid nourishment by **pinocytosis.**

(d) Mixotrophic nutrition—Some protozoans utilise more than one method of obtaining nutrients. *Euglena* is normally holophytic but absorbs simple inorganic and organic substances across its body surface in saprozoic fashion. *Balantidium* can take solid food through its cytostome. *Entamoeba histolytica* engulfs RBC and tissue fragment holozoically and dissolves host cells by enzymes it secretes. The products of cell disolution is then absorbed saprozoically.

1.64. Autotrophic or Holophytic Nutrition

Some chlorophyll bearing flagellates synthesize carbohydrates from CO_2 and water in presence of light. They synthesize proteins and fats from inorganic NH^+_4, NO^-_3 and organic substances obtained from the ambient medium. *Euglena* and other phytomastigids habitually rely on holophytic nutrition. Some protozoans containing commensal unicellular algae rely on their commensals for most of their nutritional requirements. They are **heteroautotroph.**

1.65. Reserve Food

Surplus food in protozoa is stored in the endoplasm as granules, vacuoles, globules and crystals. In holophytes **paramylum** and **leucosin** are stored. Many parasitic forms deposit glycogen. Protein surplus is stored in many holozoic forms as granules. Nucleic acids and phosphates are deposited as **volutin** granules in parasitic flagellates. Nucleoproteins in the form of **chromatoid bars** are stored in *Entamoeba* cyst. *Noctiluca* stores a large number of oil globules which help in phosphorescence.

REPRODUCTION IN PROTOZOA

1.66. Reproduction in Protozoa

Reproduction is a process by which the organism produces a replica of its own. It involves the replication of the genetic material and the cell organelles. Although genes and the nuclear substance duplicate before division is complete, yet in many cases, the organelles do not divide. One of the daughters has to differentiate them afresh.

Reproduction in protozoa is essentially the division of the simple body of the animal into two or many daughter individuals. The multiplication of a protozoan is a means for the procreation of the species. Most of the multiplicative processes in Protozoa belong to the asexual category. Sexual processes are widespread in Sporozoa, Ciliata, Foraminifera and some flagel'ate.

Reproduction in this phylum is always initiated by nuclear division which when complete sets off the cleavage of cytoplasm. A study of nucleus and mode of nuclear division in Protozoa is thus an essential prerequisite to understand the diverse methods of reproduction.

1.67. Nucleus in Protozoa

Nucleus in Protozoa varies greatly both in number and structure. The nucleus consists of :

(a) **Plastin**—an acidophilic part composed of proteins.

(b) **Chromatin**—a basophilic component of DNA, RNA and basic proteins like histones.

(c) **Endosome**—comparable to nucleolus of metazoan cell, composed of RNA and protein with basophilic staining property.

Two main types of nuclei are found in Protozoa :

(i) Dense or granular,
(ii) Vesicular.

In the dense nucleus the achromatic (not readily stainable) part has a relatively firm consistency often forming a network. The plastin my be scattered throughout or localised as an eccentric mass. The dense nucleus is quite prominent, elongate, coiled or beaded but rarely spherical. This type of nucleus is not important in reproduction and is responsible for vegetative functions. The **meganucleus** of Ciliophora belongs to this type.

In the vesicular nucleus the achromatic part is more fluid and the network, if present, is coarse. Plastin may be present in several masses usually forming a karyosome comparable to metazoan nucleolus. It is customary to use the term endosome when it is entirely composed of chromatin, and karyosome when plastin and chromatic both are present. The **micronucleus** of the ciliophora and the nucleus of majority of Protozoa belong to the vesicular type.

It is obvious that while most of the protozoans are homokaryotic the Ciliophora are the sole heterokaryotic group. Also, for reproduction purpose only the micronuclei of the Ciliophora are important. According to **Kimball** (1941) reproductive processes do not occur in artificially produced amicronucleate (—lacking micronucleus) forms. The nucleus is of paramount importance in reproduction in protozoa.

1.68. Nuclear Division in Protozoa

All types of nuclear divisions ranging from the direct or amitotic to typical mitotic are known to occur in Protozoa.

Amitosis occurs normally and regularly in many forms but it is not so common as was formerly believed to be.

In *Paramecium caudatum* the micronucleus initiates nuclear division. The meganucleus elongates without much visible change, constricts in the middle and snaps into two. The content of meganucleus undergoes solation during the amitotic division and although chromatin stains deeply no chromosome like structures are discernible. The elongate meganuclei of *Stentor*, *Spirostomum* and *Euplotes* condense into an oval shape before dividing. In *Urostyla grandis* a number of meganuclei are present which all fuse together before dividing. According to **Sonneborn** (1947, 57) the meganucleus is a compound or polyploid nucleus composed of many subnuclei. The meganucleus of *Paramecium aurelia* is said to be 860-ploid. The division segregates the many subnuclei into two random groups. Besides the meganucleus of Ciliophora the nucleus in some Myxosporidian parasites is reported to divide by amitosis.

Mitosis—or Indirect division occurs in the micronucleus of Ciliophora and the nuclei of other protozoa. A typical mitosis including division of a centriole forming the spindle of microtubules and appearance of definite number of chromosomes during nuclear division has been found in *Oxanarella*, *Acanthocystis*, *Hartmanella*, *Euglypha*, and many hypermastigids.

The first indication of mitosis is the multiplication of the centriole or its equivalent (blepharoplasts in some flagellate act as centrioles—**Manton, 1964**) and the formation of spindle of microtubular fibrils. In many Protozoa like ciliates, *Cryptomonas*, *Pelomyxa* etc., no centrioles are evident, the spindle fibrils are stretched between the opposite ends of an elongated nuclear membrane. In *Euglena* also the nuclear membrane persists throughout mitosis and surrounds an internal spindle of microtubules. Although chromosomes do appear they do not seem to move together to their poles during anaphase (**Leedale**, 1968). The endosome (=nucleolus) in many protozoans like *Euglena* and dinoflagellates persists throughout mitosis during which they also divide into two (**Sleigh**, 1973). The endosome in most other protozoa disappears during the early phase of nuclear division and is reconstituted in the daughter nuclei as in *Monocystis* and *Euglypha*.

With the use of electron microscope and better staining techniques it has become more evident that by and large nuclear division in the protozoa is similar to metozoan cell mitosis. As such there is no justification now to grade nuclear mitoses among protozoa as :

Eumitosis, Paramitosis and Cryptomitosis.

Westphal (1976) has reported that in *Aggregata eberthi* a coccidian sporozoa mitosis occurs without formation of a metaphase equatorial plate and without shortening of chromosomes. He calls this type of nuclear division as paramitosis. Most protozoologists agree that appearance of chromosomes may actually be masked by inert chromatin material in many cases of cryptomitosis reported by **Belar** (1926) and **Grasse** (1952).

Meiosis—Reductional division in which chromosome number is halved has been reported from all those protozoa reproducing by sexual processes.

Meiosis in *Monocystis rostrata*, *Actinophrys* Spp., hypermastigids, *Opalina* and ciliates is very similar to that occurring in the gametocytes of metazoa. It is slightly atypical during the conjugation in *Paramecium*. In some protozoa chromosomal halving is carried out by a single division in a so-called **one step meiosis (Grell, 1973).** Reduction division usually precedes sexual reproduction, but in Telosporidea the first division of the zygote nucleus or synkaryon is reductional.

1.69. Cytoplasmic Division

The division of the nucleus (Karyokinesis) is immediately followed by the cleavage of the cytoplasm (Cytokinesis). Some semi-autonomous organelles like chloroplast and mitochondrion may divide or are distributed between the two new organisms. Other organelles do not divide and are not shared between the two daughters individually. One inherits the old parental organelle, and the other daughter individual forms it **de novo.**

Reproduction

Although reproduction in Protozoa largely involves the division of the nucleus and the single-celled animal body yet the mode of reproduction is variable.

1.70. Multiplication in Protozoa

Basically multiplication in Protozoa takes place by two distinct methods.

(i) **Asexual reproduction,** (ii) **Sexual reproduction**

1.71. Asexual Reproduction

Asexual reproduction is the most prevalent method of multiplication in Protozoa and is found in all groups of this phylum. Even those forms which reproduce sexually also multiply by asexual processes.

The following modes of asexual reproduction are met with in

Protozoa :

(a) **Binary Fission, (b) Multiple Fission, (c) Budding.**
(d) **Plasmotomy,**
(e) **Repeated fissious with colony formation.**

(a) **Binary fission**—It is of very common occurrence. The division

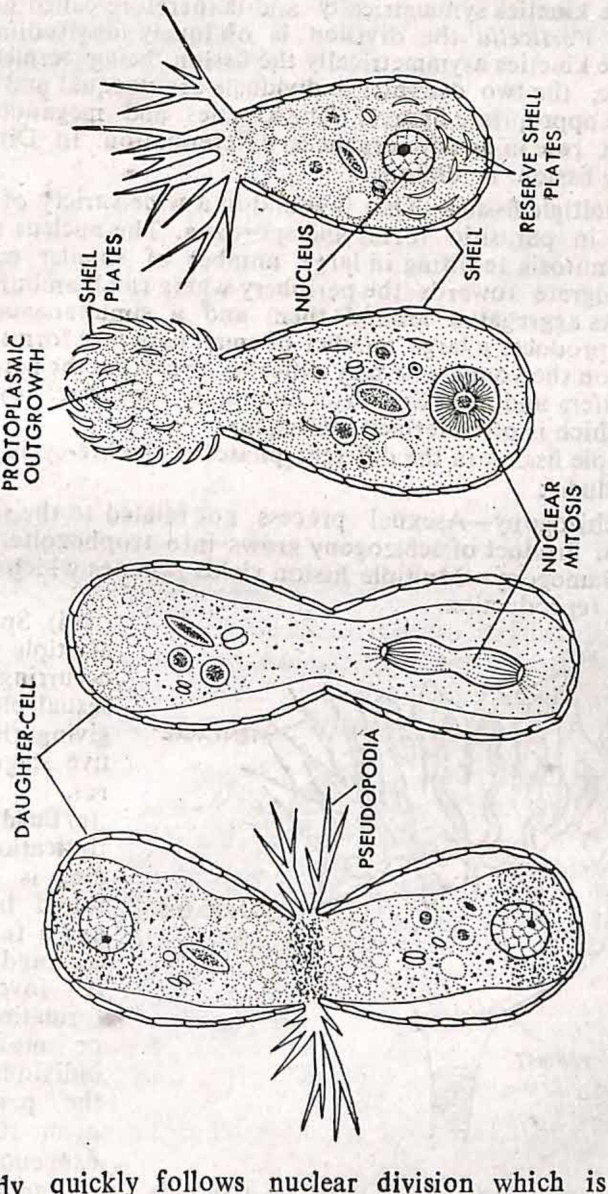


Fig. 1.66. Binary fission in *Euglypha*. Note the formation of the shell by the daughter individual.

of the body quickly follows nuclear division which is always mitotic as detailed above. The cleavage plane dividing the body during binary fission is most commonly longitudinal resulting in two equal and identical daughters. In Mastigophora as exemplified by *Euglena*, *Trypanosoma* (Fig. 1.34) and *Leishmania* division occurs by longitudinal binary fission. In shelled rhizopods like *Euglypha* and *Arcella* the division is transverse binary fission. In *Paramecium* the division is by transverse binary fission which cuts across the kineties symmetrically and is therefore called **homothetogenic.** In *Vorticella* the division is obliquely longitudinal cutting across the kineties asymmetrically the fission being termed **heterothetogenic,** the two daughter individuals are unequal and not identical (See appropriate figures). The kineties and meganucleus play important role in **de novo** organelle differentiation. In Dinoflagellates binary fission is oblique.

(b) Multiple fission—This is found in a wide variety of Protozoa specially in parasitic forms and sporozoa. The nucleus undergoes repeated mitosis resulting in large number of smaller nuclei. The nuclei migrate towards the periphery where small amount of cytoplasm gets aggregated around them and a simultaneous multiple cleavage produces a large number of small daughter forms. In multiple fission the young one may differ in form from the parent. Many Foraminifera and most Sporozoa habitually reproduce by multiple fission which is often termed **schizogony.**

Multiple fission in the different phases of the life-cycle of a protozoa include :

(i) Schizogony—Asexual process not related to the sexual phenomenon. Product of schizogony grows into trophozoite.

(ii) Gamogony—Multiple fission yields gametes which take part in sexual reproduction.

(iii) Sporogony—Multiple fission occurring after sexual phenomenon giving rise to infective stage or spores.

(c) Budding—Multiplication by budding is commonly found in Suctoria and a few flagellates and ciliates. It invovles the formation of one or more smaller individuals from the parent organism. It is either exogenous or endogenous. In exoge-

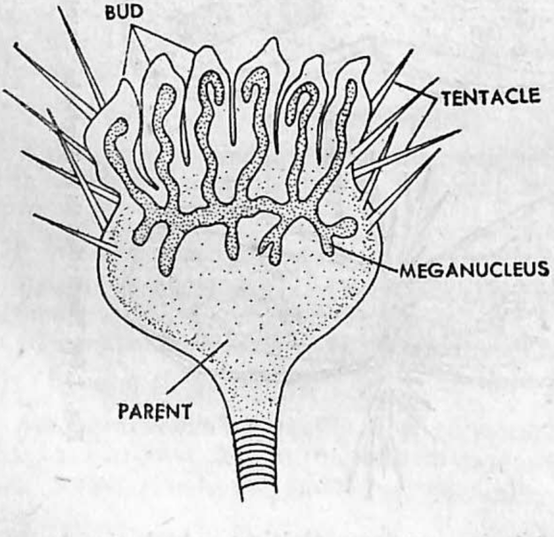


Fig. 1.67. External budding in *Ephelota*—a Suctoria

nous budding buds develop as outgrowths on the parent body which later pinch off as in many Suctoria, *Noctiluca*, Chonotricha etc. In endogenous budding the buds are produced inside the parent's body in special spaces called brood chamber as in some Suctoria, Testacea etc.

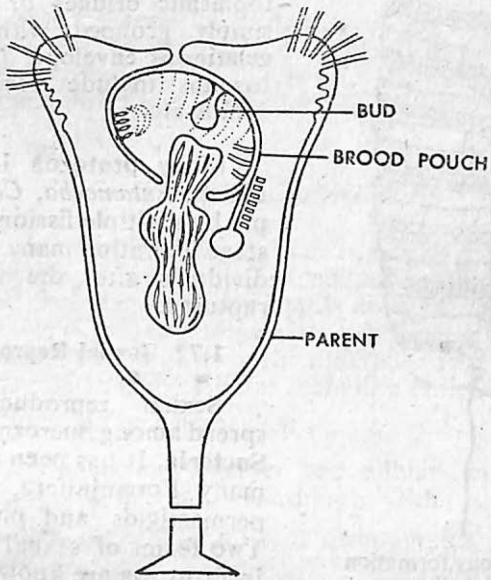


Fig. 1.68. Endogenous budding in *Acineta*

(d) **Plasmotomy**—The multinucleate *Opalina* commonly multiplies by plasmotomy. In this process cytoplasmic division occurs without division in the nuclei. Besides *Opalina*, it occurs in *Pelomyxa* and many Mycetozoa.

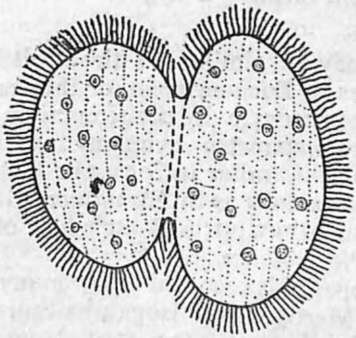


Fig. **1.69.** Plasmotomy in *Opalina*

(e) Repeated fissions with colony formation—Colonies among Protozoa are produced when nuclear division is repeated without complete separation of daughter individuals. The members of the colony may be connected by protoplasmic bridges or they may be simply grouped within a single gelatinous envelope. Colonial protozoans include *Dinobryon*, *Polykrikos* etc.

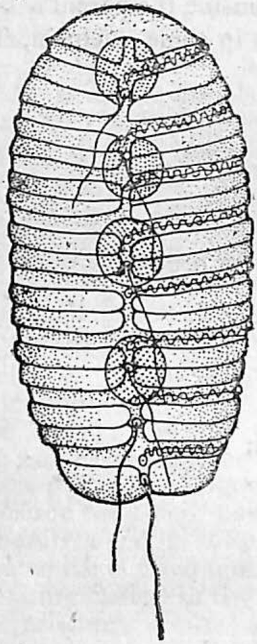


Fig. 1.70. Colony formation in *Polykrikos*

Many protozoa like *Amoeba*, *Chaos*, *Entamoeba*, *Colpoda* multiply by multiple fission in encysted stage liberating many daughter individuals after the cyst wall is ruptured.

1.72. Sexual Reproduction

Sexual reproduction is wide spread among **Sporozoa, Ciliata** and **Suctoria**. It has been reported from many Foraminifera, Heliozoa, hypermastigids and phytomastigina. Two forms of sexual reproduction in Protozoa are known :

1. Syngamy, 2. Conjugation.

Syngamy in Protozoa

This type of sexual reproduction is met with in many foraminifera, some mastigophora, *Opalina* and Sporozoa. It involves the complete fusion of two gametes, nucleus with nucleus and cytoplasm with cytoplasm forming a zygote with a zygote nucleus or **synkaryon.**

The gametes may be similar to the adult individual when it is called **hologamete** as in *Trichonympha*, or they may be produced by the adult called gametocyte by divisions termed gamogony. Such gametes are called **merogametes**. Syngamy may take place between two identical gametes similar in form and behaviour. This type of syngamy is called **isogamous** as in *Elphidium*. Gametes may be dissimilar in shape and behaviour and such type of syngamy is termed **anisogamous** as in *Plasmodium*.

Hologamous isogamy is resorted to by many caprozoic protozoa like *Copromonas*. Merogamous isogamy occurs in *Elphidium*, many other Foraminifera and most species of *Monocystis*. *Noctiluca* reproduces by merogamous isogamy.

When two gametes from the same single parent unite in syngamy it is called **autogamy**. This occurs commonly in *Actinophrys* and *Actinosphaerium*. In vast majority of protozoa the two gametes taking part in syngamy are derived from two different individuals. Such fusion of gametes is called **exogamy**.

Among the wide spectrum of mode of syngamy a trend towards evolution of sex can be traced. In many advanced Sporozoa the gametes are not only dissimilar but their behaviour and accumulation of nutrient in them justifies their identification as male and female gametes.

Conjugation in Protozoa

Sexual reproduction by conjugation is largely restricted to the Ciliophora. It takes place either as a simple mutual exchange of nuclear material between two conjugants as in *Paramecium*, or the union of two nuclei of two conjugants behaving as gametes as in *Vorticella*. Definite mating types in the different varieties or syngens have been recognised in many ciliates including *Paramecium*.

During conjugation in *Paramecium* :

(i) Two individuals come together and adhere with their oral surface, their cytoplasm becoming continuous with one another.

(ii) Meganucleus in each conjugant disintegrates into the respective cytoplasm.

(iii) Micronucleus divides twice in each conjugant, the last is a reductional division. Out of the four nuclei produced three are absorbed in the cytoplasm with only one nucleus remaining in each conjugant.

(iv) The single nucleus divides forming two pronuclei—one is motile or male pronucleus and the other is stationary or female pronucleus.

(v) The male pronucleus of the conjugant moves towards the female pronucleus reciprocally and fuses with them yielding a synkaryon in each conjugant.

(vi) The conjugant separates and becomes ex-conjugant.

(vii) In *P. caudatum* the synkaryon divides thrice yielding eight nuclei, four of them become micronuclei and four transform into meganuclei. Three of the four micronuclei are absorbed in ex-conjugant's cytoplasm. The ex-conjugant now carries one micronucleus and four meganuclei. It undergoes cytoplasmic division preceded by micronuclear division which occurs twice. The meganucleus does not divide and is simply apportioned to the 4 daughter individuals. Thus each ex-conjugant produces four daughter *Paramecium caudatum*. The diagrammatic representation of conjugation in *Paramecium* is given in figure 1.52.

In *P. aurelia* each ex-conjugant produces two daughter individuals each with one meganucleus and two micronuclei.

In *Vorticella* conjugation is strikingly different from *Paramecium* which may be an adaptation for the former's sessile existence. The conjugants in *Vorticella* are not incipiently ☿ as they are in *Paramecium* and there is a tendency towards differentiation of sex. The microconjugant behaving like a male gamete and the megaconjugant acting as a female. There is a much greater fusion of the cytoplasm and only one pronucleus is functional in each conjugant. Conjugation in *Vorticella* tends towards syngamy. In the process of conjugation cytoplasm of the conjugants is enriched by breakdown of effete meganucleus and some micronuclear material. New genetic combinations arise from the fusion of pronuclei.

Many aberrant forms of conjugation are found in the species of *Paramecium*. They are :

Autogamy—This has been reported from *P. aurelia*. The fusing nuclei are derived from the micronuclei of the same individual. All the processes of conjugation i. e., micronuclear division and fusion of pronuclei occur within the single individual of *P. aurelia* (Fig. 1.53).

Endomixis—It is a type of nuclear reorganisation with a single individual of *P. aurelia* without nuclear division and nuclear fusion.

Hemimixis—In certain species of *Paramecium* small fragments of the meganucleus fall apart and are absorbed in the cytoplasm. The remaining part of meganucleus reorganises itself and conducts the vegetative functions with renewed vigour. No change takes place in the micronucleus.

1.73. Reasons for Peculiarities in Sexual Reproduction in Protozoa

The peculiarities in the sexual processes of Protozoa are in part an inevitable consequence of their small size, simplicity of structure and often complex life-cycles. Anisogamy and differentiation of sex have evolved independently in many families of protozoa and have tended towards oogamy in extreme cases. Sexes may be said to exist in Protozoa but rarely the sexes are apparent. The best examples of differentiation of sex are provided by *Plasmodium* and *Eimeria*.

Sexual reproduction in Protozoa is interspersed with asexual phenomenon. Sexual reproduction in such forms brings about their periodic rejuvenescence and throws up new genetic combinations.

1.74. Conclusion

Protozoa reproduce extensively by asexual means and many multiply exclusively by this method. Asexual means result in rapid increase in the population for fuller exploitation of localized sources of food. Absence of sexual phenomenon is an adaptive feature for rapid build up of the population.

Sexual reproduction is often present in forms where the transmission of the organism from host to host is involved.

PARASITISM IN PROTOZOA

1.75. Parasitism is an association of two organisms in which one organism lives at the expense of the other giving nothing in return. The former is called a parasite and the latter its host. Parasitism is a specialised mode of life and various levels of it are found in the phylum Protozoa. **Facultative parasits** are those that can live for various lengths of time without the host whereas **obligatory parasites** are those forms which cannot normally survive when separated from their host.

Those parasites that simply live on the external parts of their hosts are called **ectoparasite** Parasites found inside the body of their host are termed **endoparasite** The ectoparasite does not show much adaptive features in its structure and biology. The endoparasites show modifications in their structure and physiology. Many parasitic protozoa cause harmful effects on their host and produce disease. Such forms are called pathogenic parasites.

1.76. Ectoparasitic Protozoa

A few species like *Hydramoeba hydroxena* (found on epidermis of *Hydra*), *Costia necatrix* (parasitic on the epidermal cells of fishes) and *Ichthyophthirius multifilis* (inhabiting in the skin of fishes) are ectoparasitic. They feed on the superficial host cells, dissolve and feed on the liquefied host cells causing varying degrees of cellular necrosis. *I. multifilis* causes 'ich' in fishes. The ciliate parasite multiplies within the skin causing small 'tumours', which cause erosion of the skin. These parasites are transferred directly from host to host. Both *Costia,* a flagellate and *Ichthyophthirius,* a ciliate retain their locomotor organelle and possess all structures that are present in their free-living relatives. They thus exhibit very little adaptive modification. Ich causes great damage to fishery.

These ectoparasitic protozoa are shown in the diagram below :

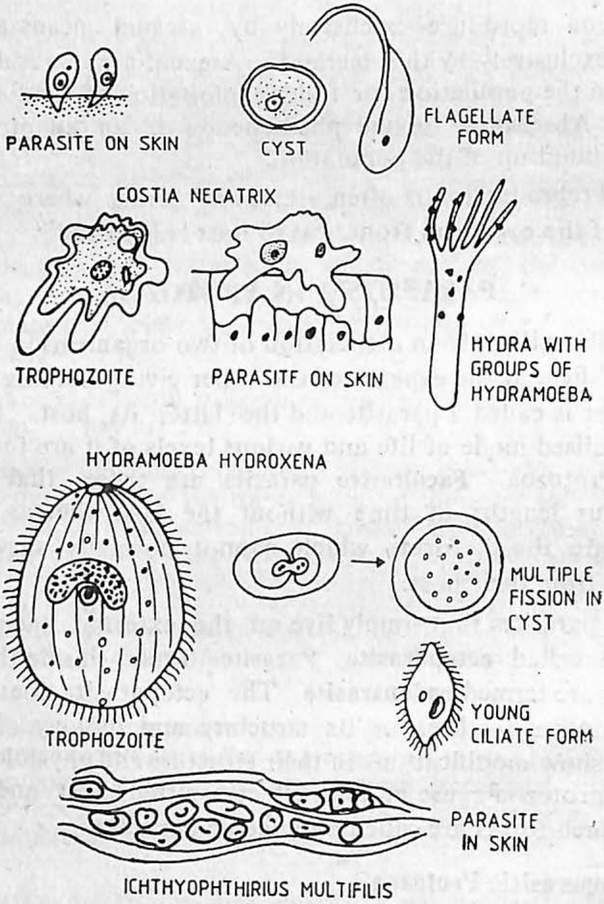


Fig. 1.71. Some ectoparasitic protozoa

1.77. Endoparasitic Protozoa

Protozoa belonging to many different orders are endoparasitic in a' wide variety of animals. Many are pathogenic parasites of man and his domestic animals. The entire class Sporozoa (=Subphylum Sporozoa) is composed of parasitic forms.

Some of the more important protozoan parasites are listed below :

Class Sarcodina

Entamoeba histolytica—causes amoebic dysentery and abscess in man.

E. gingivalis—aggravates pyorrhoea and caries in man.

Dientamoeba fragilis—causes dysentery in man.

Class Mastigophora

Histomonas meleagridis—causes blackhead in turkey.
Hexamita Spp—causes enteritis in fowl and turkey.
Giardia intestinalis—causing giardial dysentery in man.
Trichomonas tenax—infects buccal cavity of man.
T. vaginalis—infects urinogenital tract of human being.
Chilomastix masnili—inhabits large intestine of man.
Trypanosoma gambiense—causes human sleeping sickness.
T. rhodesiense—causes human sleeping sickness.
T. cruzi—causes Chagas' disease in man.
T. brucei—causes Ngana in horses etc.
T. evansi—causes Surrah in horses.
T. equinum—causes Dourine in horses.
T. equiperdum—causes Mal de Caderas in horses.
Leishmania donovani—causes Kala-azar in man.
L. tropica—causes Oriental or Baghdad sore in man.
L. braziliense—causes Espundia in man.
Cryptobia Spp.—causes anemia in fishes.

Class Ciliata

Balantidium coli—causes balantidial dysentery in human being.
Nyctotherus spp—inhabits gut of various invertebrates.

Class Sporozoa

Isospora hominis }
Adelea spp. }—infects man and other mammals.
Eimeria steidi }
E. perforans—affects liver of rabbit etc.
E. tenella and
E. necatrix—affects gut of fowl.
E. parva, E. imbricata—necroses small intestine mucosa of sheep.
E. bovii, E. zurnii—affects hindgut of cattle.
Nosema apis—affects honey bee.
N. bombycis—causes pebrine in silkworm.
Babesia bigemina—causes Red Cattle fever.
Theleira spp.—affects cattle.
Haemoprotens spp.—affects pigeon and other birds.
Leucocytozoon andrewsi—affects fowl.
Leucocytozoon spp.—affects duck etc.
Plasmodium Vivax }
P. ovale— }—causes human malaria.
P. malariae }
P. falciparum }
P. cynomolge—bird and monkey malaria.

Endoparasitic protozoa may be cytozoic or intracellular in the host cell, histozoic or intercellular in the host tissue, coelozoic i. e., living in body fluid, body spaces, lumen of gut and other tracts. These parasites absorb nourishment from the vital fluids of their host, feed on the host cell either phagocytically or holozoically or after dissolving the host tissues and cells by secreting proteolytic enzymes. They cause abnormal and pathological changes in the host, in their cells, tissues, organs and often alter the nature of their body fluids. The multiplication of *E. histolytica* in the submucosa of colon leads to necrosis of mucosal and submucosal tissue producing flask-shaped intestinal ulcers. The parasite often dissolves away the endothelial wall of blood capillary causing loss of blood. It may enter the capillaries so ruptured and carried by portal circulation to liver. Once in the liver it starts the necrosis of hepatocytes and produces liver abscess. From liver they may be carried to other secondary sites like kidney, diaphragm etc. There also they cause dangerous destruction of tissues and cells causing abscess in these areas.

Balantidium coli sometimes causes similar necrosis of colon mucosa. The amoebic and balantidial ulcers may be secondarily infected by bacteria thus aggravating the dysenteric symptoms.

The haemoflagellates, *Trypanosoma* and *Leishmania* also produce far reaching pathological changes in the body of the host. *T. gambiense* causes enlargement of lymph glands, spleen, followed by changes in the meninges and increase in cerebrospinal fluid. The walls of the blood vessel are thickened and perivascular infiltration of granular substance occurs in the brain. The albumin/globulin ratio in plasma is altered serum Ca^{++} is lowered and clotting time of blood is reduced. *T. cruzi* causes degeneration of infected host cells and diapedesis (infiltration from the blood vessel to its surrounding area) of leucocytes causes inflammation which is followed by fibrosis of infected tissue. *L. donovani* elicits an increase in the count of large macrophages and mononuclears together with massive destruction of cells of reticulo-endothelial system and enlargement of spleen and other lymph glands.

Plasmodial infections in man is accompanied by enlargement of spleen, decrease in RBC count, thinning of blood plasma and various leucocytal abnormalities. In severe cases of infection by *P. falciparum* the capillaries in brain and spleen may be completely blocked with infected RBC leading to death. The toxins released by various parasites of the blood cause rise in body temperature and reduced resistance to infections.

Majority of microsporidia are cytozoic causing degenerative hyperplasia of the host cells. When gonads are parasitized the germ cells of the host fail to mature and lead to a sort of parasitic castration. Myxosporidian parasites are either histozoic or coelozoic and the host tissue undergoes various pathological changes. *Nosema apis* attacks the intestinal epithelial cells of honey-bee, but the ovary also degenerates to various degrees. *Orchitophrya stellarum* breaks down the germinal epithelium of the testis of the starfish, *Asterias rubens*. *Nosema bombycis* often multiplies in the ovary of the silkworm and is transmitted from generation to generation through infected eggs.

Parasitic protozoa are usually simplified in their structure. They donot possess any elaborate organelle (except the ciliate parasite). The protozoans living inside cells and tissue show maximum structural simplicity. They lack contractile vacuoles, locomotory and ingestory organelles. However, coelozoic forms like *Trichomonas*, *Giardia*, *Balantidium* possess locomotory and ingestory organelle.

Surplus food is stored as glycogen, volutin granules and chromatoid bodies. Many parasitic protozoa are both anaerobic and aerobic depending on the availability of oxygen inside the host. Species of *Plasmodium*, *Leishmania* and *T. cruzi* are aerobes. Other species of *Trypanosoma* and intestinal parasites like *Entamoeba*, *Trichomonas* etc. are anaerobic.

In sporozoan blood parasites metabolic wastes may be temporarily stored in the cytoplasm as pigmented granules Ex. haemozoin of *Plasmodium* spp.

[1.78. Most parasitic protozoa establish a definite host-parasite relationship. A parasite's existence is usually an elaborate compromise between obtaining sufficient nourishment to maintain and propagate itself without impairing too much the vitalities of the host. While parasitism causes profound changes in the parasite, it also presents the parasite with greater obstacles in reaching their host and spreading in the population of the host species. Many adaptations in the life-cycles of parasitic protozoa are aimed towards overcoming these obstacles. The life-cycle of a parasitic protozoa is largely geared to two objectives :

(a) production of a large number of offspring.

(b) ensuring transmission of as many individuals as possible to a fresh host.

Multiple fission is the most common mode of reproduction in parasitic protozoa. By this process a large number of offspring can be produced which is one way of ensuring that enough parasites are available for transmission from one host to another. Binary fission is more common in intestinal amoebae and intestinal flagellate. Some haemoflagellates multiply by repeated binary fission. To gain access to a fresh host many intestinal protozoa produce resistant encysted stage at an opportune time in the life-cycle. The cysts serve both as means of further multiplication and for passage into a fresh host along with food and drink.

Sporozoan parasites are characterised by possessing both asexual and sexual reproductive processes. Their reproductive potential is consequently very high. Multiple fission occurs both asexually—Schizogony and after syngamy—sporogony as in *Plasmodium*. The zygote of a sporozoan is usually protected by a cyst (except haemosporidea) forming a sporocyst inside which it divides to produce many infective stages or sporozoites. In *Monocystis* and other gregarinida transmission is direct by means of the encysted spore containing the sporozoites. In *Plasmodium* transmission is cyclical through the agency of a female *Anopheles*. Schizogony occurs in man (in liver cells and erythrocytes) and sporogony takes place in the mosquito. Transmission is cyclical and inoculative in haemoflagellates also. In these parasites the protozoan undergoes a definite cyclical change in the vectorial host which concludes with the production of a large number of infective or metacyclic stage. Under certain conditions mechanical transmission with the blood-sucking insect merely acting as a syringe and needle is possible. Certain species of *Trypanosoma* like *T. equinum* and *T. equiperdum* have eliminated the need of a vector and are passed from host to host by direct contact. Similarly, two spp. of *Entamoeba*, viz , *E. histolytica* and *E. coli* are transmitted from host to host in encysted stage by contaminative method, but *E. gingivalis* is passed from man to man by direct contact eliminating the necessity of cyst formation. Intestinal flagellates and ciliates are also transmitted by contaminated food and drink in the cyststage.

1.79. It is generally believed that parasites have evolved from their free-living relatives. Parasitism in protozoa probably arose in the beginning by ingestion by the host of some free-living forms. Some of these may have found conditions of life satisfactory in the gut of the animals which devoured them. In course of time such forms possibly became adapted to the new environment. They eventually have lost the power to live and reproduce outside the body of their hosts. Such parasites may have first occurred in the gut of blood-sucking insects, leeches etc., and were subsequently transmitted to a vertebrate host in which they started living as a parasite. This view may be supported by the fact that many genera of intestinal parasites of man like *Entamoeba*, *Trichomonas*, *Giardia*, *Chilomastix*, *Balantidium* etc., have related forms in leeches, earthworms, fishes and amphibians. Some of the haemoflagellate genera, also, possess related species in many other vertebrates.

The phenomenon of hyperparasitism – a parasitic protozoan living in another parasitic protozoan – is also known. The microsporidian *Nosema notabilis* is an exclusive parasite of the myxosporidean parasite, *Sphaerospora polymorphus*.

1.80. In parasitic protozoa, asexual reproduction in the life-cycle is more frequent and predominant form of reproduction. This is because sufficient number of parasites have to be produced for any efficient exploitation of the host. The absence of sexual reproduction in certain protozoan parasite is however a secondary feature. Like all parasites, the protozoan life-cycle shows adaptations along two lines :

(a) A phase of growth and asexual multiplication is present whose duration is dependent on the nutritional value of the host tissue.

(b) A phase of encystment or protected stage which serves, both as a means of surmounting adverse circumstances and transmission from host to host.

In view of the above the life-cycle of an endoparasitic protozoan is usually complex. A premium is placed on ensuring transmission to a fresh host. In haemosporidea and similar 'digenetic' forms (parasites completing their life-cycle in two kinds of hosts) an alternation of sexual and asexual phases which is geared to the adaptation for transmission of enough offsprings through the agency of an insect vector (an intermediate host which serves both as a haven for the parasite and helps transmit it from one host to another) from host to host.

OSMOREGULATION IN PROTOZOA

1.81. Osmoregulation involves the maintenance of water and solute (ions, minerals, nonelectrolytes) content of the body at a steady level. Protozoa mostly live in aquatic environment. They are affected by the osmotic pressure of the medium in which they live.

The body of a large number of protozoa is bounded by a simple plasmalemma, in others a pellicle with varying degrees of firmity reinforces the plasmalemma, in still others most of the body is encased in a calcareous or siliceous shell built on the plasmalemma. The cytoplasm of all these protozoans contain numerous organic materials, ions, minerals etc., dissolved in the aqueous phase. Consequently the cytoplasm develops an osmotic pressure which is much higher than that of fresh water in which most of them live. This osmostic gradient, from outside to inside, causes a passive inflow of water into the protozoan body. Water continually diffuses from the hypotonic external environment through the permeable body surface into the cytoplasm. The passive inflow is obviously more rapid in the naked forms bounded only by a plasmalemma than in shelled-forms.

In marine protozoa the situation is different. Owing to considerable salt content the osmotic tonicity of sea-water is quite high as compared to fresh water. Marine protozoans thus do not face an osmotic stress. The constant fluxes of salts (ions) and water keep the osmotic tonicity of marine protozoa in approximation to that of sea water.

To counteract the osmotic flooding of the cytoplasm, fresh-water protozoa have evolved a 'water-baling out' system in the form of contractile vacuole. The contractile vacuole, often called pulsating vacuole due to its rhythmic pulsations (dilation and contraction), is the osmoregulatory organelle of protozoa. The best developed contractile vacuole is found in the ciliates and the simplest in sarcodina. The contractile vacuole increases in size by imbibing end accumulating fluid from the surrounding cytoplasm. This phase is called **diastole.** When the contractile vacuole attains its maximum size it reaches the surface of the body and contracts emptying its fluid content to the exterior. This is called **systole.**

The contractile vacuole in protozoa is variously distributed. In most species of *Amoeba* the contractile vacuole is single and simple and is located more toward the posterior end which is called the uroid. In orders Testacea and Heliozoa the vacuole is located in the ectoplasm and the body surface bulges out above it during diasotle. In mastigophora the contractile vacuole is usually single and tends to be located near the anterior end. In *Euglena viridis*, it is surrounded by a number of secondary vesicles. The secondary vesicles accumulate fluid and pass it into the contractile vacuole. The latter then empties into the reservoir or flagellar pocket through which the fluid is passed to the exterior. In ciliata one to a few contractile vacuoles are disposed in the body in a constant location. A pore in the pellicle is situated directly above the discharge canal leading out from the contractile vacuole. The fluid content of the vacuole is discharged through this. In *Balantidium* and *Nyctotherus* the contractile vacuole is situated close to the permanent **cytopyge** located at the posterior end through which it empties its content. In *Paramecium caudatum* a pair of contractile vacuole is found one near each end of the animal. Each is surrounded by 5-7 radially disposed feeder canals. The contractile vacuole in *Stentor* is associated with two feeder canals, one disposed longitudinally and the other surrounding the peristomial rim. It is large in size in *Spirostomum* occupying most of the posterior end. Its single feeder canal is very long and extends to the anterior end of the protozoan. In many other ciliates feeder canals are not found.

The contractile vacuole and the feeder canals of *P. caudatum* have been studied by **Schneider** (1957) and **Jurand** and **Selman** (1969). The contractile vacuole is a large central bladder which is filled up by 5-7 radially disposed feeder canals. A feeder canal consists of:

(i) a pointed end portion or terminal part which imbibes fluid from the adjacent cytoplasm,

(ii) a middle part or ampulla which swells up markedly during the diastole of the feeder canal, and

(iii) a short neck or injector canal through which fluid is pushed into the contractile vacuole.

The end portion or terminal part of feeder canal is surrounded by a specialised area of cytoplasm which appears under the electron microscope as a delicate network of branched tubules closely associated with the cisternae of endoplasmic reticulum. The fluid from these branching tubules enters the terminal part of the feeder canal. The contractile vacuole is dilated when fluid from the feeder enters it. The feeder canals thus undergo systole to cause diastole canal in the contractile vacuole. The two components of the osmoregulatory organelle thus pulsate out of phase with one another.

During diastole of the feeder canals the connection between the terminal part and the branched tubules is retained, but when they undergo systole this connection is closed preventing the backflow of fluid. Bundles of fibrils run from the feeder canal to the membrane of the contractile vacuole running above it and reaching the margin of the discharge canal. These fibrils, which are composed of microtubule, are probably contractile and contribute to the systolic mechanism of the vacuole. The osmoregulatory organelle of *Paramecium* is shown in Fig. 1.50.

The formation of the contractile vacuole in some amoeboid protozoa like *Naegleria gruberi* begins with a number of small vesicles which ultimately fuse to form a single contractile vacuole. The contractile vacuole of *Amoeba verrucosa* can be removed from the animal and its membrane has been studied by **Pappas** (1959) with electron microscope. The membrane is structurally similar to a cell membrane or a unit membrane. The membrane of the contractile vacuole is surrounded by several small vesicles and mitochondria. According to **Mercer** (1959) some of the vesicles are in direct continuity with the contractile vacuole.

The rhythmic appearance and disappearance of the contractile vacuole are preceded not only by membrane contraction but also by its breakdown in systole and reformation during diastole. Isolated contractile vacuoles of *Amoeba proteus* keep their rhythmic contraction if provided with *ATP* and Mg^{++}. The contractility of the contractile vacuole is therefore energy dependent and the external surface of the contractile vacuole is connected with contraction.

Contractile vacuoles are thus formed by

(a) coalescence of many small spherical vesicles as in *Naegleria* and *A. proteus*,

(b) filling with fluid from channels in cytoplasm as in *Euglena* and *Paramecium*,

(c) filling with fluid directly from cytoplasm as in *Balantidium*.

Kitching (1957) was the first to suggest that freshwater protozoa use their contractile vacuole for active transport in voiding water. Water enters the protozoan body in response to concentration gradient. It leaves the protozoa against concentration gradient. Every systole thus removes some water from the cytoplasm to the outside. The frequency of vacuolar pulsation in marine and parasitic protozoa is much lower than that in freshwater forms because of the small osmotic pressure difference between the protozoan cytoplasm and the environment. Many marine protozoans have lost their contractile vacuole as they have no use of it. The rate of contraction of the contractile vacuole is not only influenced by the salt and solute content of the medium in which protozoa live but also by temperature and presence of other substances like metabolites and toxicants. The pulsations are slower at low temperature and rapid at high. This also indicates that vacuolar function is energy dependent.

In *A. proteus* a contractile vacuole of 50µ*m* diameter pulsates every 5 minutes, in *P. caudatum* it reaches full diastole size of 10µ*m* every 5-10 seconds. In *Spirostomum* the very large vacuole pulsates slowly at 30-40 minutes interval. Every 15-20 minutes a *Paramecium* removes through its contractile vacuole a quantity of water equal to its body volume.

Variations in the volume of fluid removed by a contractile vacuole as required by changes in the water content of the body may be obtained by change in the volume of the contractile vacuole or by change in frequency of pulsation. The rate of water expulsion is high in small protozoa and low in large protozoa.

The freezing point depression of the vacuolar fluid has been determined for a number of protozoa (**Westphal,** 1976). The fluid content of the contractile vacuole has a freezing point depression (a colligative property and indicator of osmotic pressure) about 1/3 of that of the cytoplasm but 3 times that of the surrounding water. As the vacuolar fluid is hypotonic to cytoplasm and because there is a continuous osmotic inflow of water in the protozoan body, it is believed that some active transport of water into the vacuole or of solutes out of the vacuolar fluid takes place. It is possible that metabolic products and nitrogenous wastes may be removed along with water by the contractile vacuole. **Sleigh** (1973) reports that although urea has been found in the vacuolar fluid of *Spirostomum* in most other protozoa of small size wastes diffuse out of the general body surface.

Many dinoflagellates possess small vacuoles called **pusule.** Pusules open by canaliculi near the bases of the transverse flagellum. Their pulsations are less frequent and irregular as compared to the contractile vacuole. According to **Dodge** (1972) they are a unique osmoregulatory organelle of the dinoflagellates. Occasionally the pusules form an extensive system of vacuoles and canals in a specialised vacuolated region of the dinoflagellate body.

The contractile vacuole is the major osmoregulatory organelle. When a *Paramecium* is poisoned with very dilute cyanide solution its respiration is suspended and the vacuole stops functioning. The animal fails to osmoregulate, swells up and ultimately bursts. The exact mechanism of contractile vacuole filling is not known. However, 4 mechanisms have been proposed :

1. Hydrostatic pressure causes filling of the contractile vacuole,

2. Water is secreted by the cytoplasm into the vacuole,
3. Solute is first secreted into vacuole and water diffuses subsequently, and
4. Active transport of water fills the vacuole.

The consensus is that water fills the contractile vacuole or its feeder canals by active transport and the expulsion of the vacuolar fluid is brought abous by the contractility of the membrane bounding the vacuoel.

* * *

2. PHYLUM PORIFERA

(*L.*, *Porous* = **pore**; *ferre* = **to bear**)

2.1. The name Porifera to this Phylum was given by **Robert E. Grant** (1936). Porifera means 'pore bearers'. This Phylum includes a group of animals which bear numerous minute pores throughout the surface of the body and are usually called sponges.

2.2. General Characters

(i) All sponges are aquatic, mostly marine but a few are freshwater.

(ii) They are multicellular organisms with cellular grade of body organisation without forming tissues or organs.

(iii) They are sessile, solitary or colonial.

(iv) They have asymmetrical or radially symmetrical bodies.

(v) The body is cylindrical, tubular or vase-like.

(vi) The body wall is **diploblastic** with outer dermal epithelium and inner gastral epithelium with a gelatinous non-cellular **mesenchyme** in between.

(vii) The body surface bears numerous minute pores i.e., **Ostia** for the ingress of water.

(viii) They possess peculiar **canal system** through which water current flows drawing food and oxygen inside the body and carrying away excretory and reproductive products.

(ix) Internal skeleton is present in the mesenchyme in the form of calcareous or siliceous **spicules** or of proteinous **spongin fibres.**

(x) There is no definite organ system in the body.

(xi) Digestion is entirely intracellular.

(xii) Nervous and sensory cells are lacking.

(xiii) All sponges possess great power of regeneration.

(xiv) They are mostly bisexual but asexual forms also exist.

(xv) Reproduction takes place both by asexual and sexual method. Asexual reproduction takes place by budding, fission or **gemmule** formation and sexual reproduction by **sperms** and **ova.**

(xvi) Fertilization is internal and at the same time it is cross fertilization.

(xvii) Cleavage is holoblastic and development is indirect followed by a free swimming ciliated larva, the **amphiblastula** or **parenchymula.**

2.3. Classification

Phylum Porifera has been sub-divided into three classes based primarily on the nature of the skeleton. The three classes are as follows :

Class 1 : Calcarea

This class comprises calcareous sponges as their skeleton or spicules are made of calcium carbonate. (L., *Calcis* = **lime**; Gr., *sponges* = **sponge**.)

Characters :

(i) Members of this class are smaller in size, extending up to 15 cm in length and may be solitary or colonial.
(ii) The body shape is usually cylindrical or vase-like.
(iii) The osculum is narrow, terminal and fringed with bristles.
(iv) The skeleton consists of separate calcareous spicules which may be monaxon, triradiate or tetraradiate.
(v) The collar cells are comparatively of larger size.
(vi) The canal system is ascon, sycon or leucon type.
(vii) The colour of the body is white or dull-brown.
(viii) They are exclusively marine and occur in shallow coastal water.

Class Calcarea is divided into two orders :

Order 1—Homocoela

(i) The body is small, cylindrical and thin-walled without internal folds.
(ii) The canal system is simple or ascon type.
(iii) The spongocoel is lined throughout by choanocyte cells.

Ex. *Leucosolenia.*

Order 2—Heterocoela

(i) The body is comparatively bigger, vase-like and thick-walled with internal folds.
(ii) The canal system is sycon and leucon type.
(iii) Only the flagellated chambers are lined by choanocyte cells.

Ex. *Grantia*, *Sycon* (*Seypha*).

Class 2. Hexactinellida or Triaxonida or Hyalospongiae

This class comprises glass sponges having triaxon or hexactinal spicules made of silica. (Gr., *hexa* = **six** or *tri* = **three**; *action* = **rays**; *hyalos* = **glass**; *sponges* = **sponge.**)

Characters :

(i) Members of this class are of moderate size, extending up to 1 metre in length and are usually solitary.
(ii) The body shape is usually cylindrical, cup-shaped or funnel-shaped.
(iii) The osculum is wide and usually covered over by a siliceous sieve plate.
(iv) The skeleton consists of **triaxon** or **hexactinal** siliceous spicules, often fused resembling spun glass.
(v) Dermal epithelium is wanting.
(vi) The canal system is simple rhagon type.
(vii) The choanocyte cells are restricted to finger-like flagellated chambers.
(viii) They are exclusively marine and occur chiefly in tropical deep sea water.

Class Hexactinellida is divided into two orders :

Order 1—Hexasterophora

(i) The beautiful glass like body is cylindrical, very light and attached to the substratum directly.
(ii) The spicules are hexasters having star-like appearance.
(iii) The flagellated chambers are radially and regularly arranged.

Ex. *Euplectella* (Venus's flower basket).

Order 2—Amphidiscophora

(i) The body is usually rounded or oval and attached to the substratum by root tufts.
(ii) The spicules are **amphidises** having a convex disc, bearing a crown of backwardly directed marginal teeth at both ends.
(iii) The flagellated chambers are irregularly arranged.

Ex. *Hyalonema* (Glass rope sponge).

Class 3. Demospongiae

This class comprises diverse and complicated sponges with skeleton of siliceous spicules or spongin fibres or a combination of both or totally absent. (Gr., *demos* = **frame**; *spongos* = **sponge**.)

Characters :

(i) Members of this class are highly organised, varying from small to large size and may be solitary or colonial.
(ii) The body shape is variable being rounded, oval, cup-like, funnel-like or cushion-like.

(iii) The skeleton is composed of siliceous spicules or spongin fibres or a combination of both or none.

(iv) The siliceous spicules are monaxon or tetraxon.

(v) The canal system is complicated and leucon type.

(vi) The choanocyte cells are restricted to small and rounded flagellated chambers.

(vii) The body is generally compact and brightly coloured.

(viii) They are mostly marine but a few are fresh-water and occur in shallow as well as deep water.

Class Demospongiae is divided into three sub-classes :

Sub-class I. Tetractinellida

(i) The body is rounded or flattened with dull to brightly coloured, occurring in shallow water.

(ii) Siliceous spicules, if present, are tetraxon and sometimes totally absent.

(iii) Spongin fibres are absent.

Sub-class Tetractinellida is divided into three orders :

Order 1—Myxospongida

(i) The body surface is velvet like and the structure is simple.

(ii) The spicules are lacking.

Ex. *Oscarella.*

Order 2—Carnosa

(i) The structure is homogeneous.

(ii) Equal-sized spicules are present.

Ex. *Chondrilla.*

Order 3—Choristida

(i) The body form is usually elaborate.

(ii) Both small and large sized spicules are present.

Ex. *Geodia, Ancorina.*

Sub-class 2. Monaxonida

(i) The body form is variable, occurring in shallow as well as deep water.

(ii) The skeleton consists of monaxon spicules distinguished into megascleres only.
(iii) Spongin fibres may or may not be present.

Sub-class Monaxonida is divided into four orders :

Order 1—Hadromerina

(i) Megascleres are mostly tylostyles i.e., the broad end is knobbed.
(ii) Microscleres are usually absent and if present, are star-like.
(iii) Spongin fibres are absent.

Ex. *Cliona* (Boring sponge).

Order 2—Halichondrina

(i) Megascleres are always of more than one kind.
(ii) Microscleres are usually absent.
(iii) Spongin fibres are present but they are very scanty.

Ex. *Halichondria.*

Order 3—Poecilosclerina

(i) Megascleres are usually of two or more kinds and united by spongin fibres into a regular network.
(ii) Microscleres may be curved, bow-shaped or C-shaped.

Ex. *Myxilla.*

Order 4—Haplosclerina

(i) Megascleres are always diactinal and pointed at both ends.
(ii) Microscleres may or may not be present.
(iii) Spongin fibres are usually present.

Ex. *Chalina, Spongilla* (fresh-water).

Sub-Class 3. Keratosa

(i) The body form is usually rounded and massive with a leathery surface and dark colour, occurring generally in warm shallow water.
(ii) The skeleton is exclusively composed of spongin fibres.
(iii) The spicules are totally absent.

Ex. *Euspongia* (Bath sponge), *Hippospongia* (Horse sponge).

2.4. Skeleton of Sponges

The skeleton of sponge consists of spicules or spongin fibres or a combination of both i.e., spicules + spongin fibres.

The **spicules** also called **sclerites** are definite bodies having a crystalline small appearance and consist of simple spines or of spines radiating from a point. The spicules or sclerites of spongin fibres or both form the sponge skeleton. The spicules have an axis of organic material surrounded by inorganic substance, either $CaCO_3$ (in Calcarea) or clear glassy hydrated silica (in Hexactinellida). The great variety of shape presented by the spicules help in identification of sponges. They can be distinguished as large spicules called **megascleres** or small spicules called **microscleres.**

Megascleres—These may be of the following types :

A. Monaxon Spicules—These are formed by growth in one or both directions along a single axis. When growth occurs in one direction the spicule is called **monactinal monaxon** or a **style.** A style is typically rounded at one end and pointed at the other end. It may be—

(i) **Tylostyle**— when the broad end is knobbed.

(ii) **Acanthostyle**—when style is covered by thorny processes.

When the monaxon spicule grows at both ends from a central part it forms the **diactinal monaxons** (rhabds or diactines). These may be :

(i) **Oxeas** — when pointed at both ends.

(ii) **Tornotes**—when lance-headed at each end.

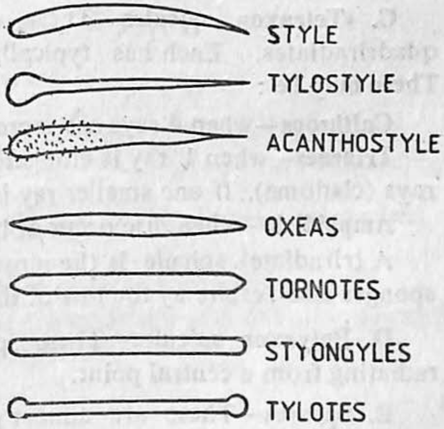


Fig. 2.1. Different types of monaxon spicules

(iii) **Stryongyles**—when rounded at each end.

(iv) **Tylotes**—when like pin-head at each end.

B. Triaxon Spicules—These are also called hexactinal and occur only in the hexactinellida. Each consists of 3-axes crossing at right angles. Thus six rays appear which extend from a central point at right angles to each other. This can give many variations by loss or reduction of rays.

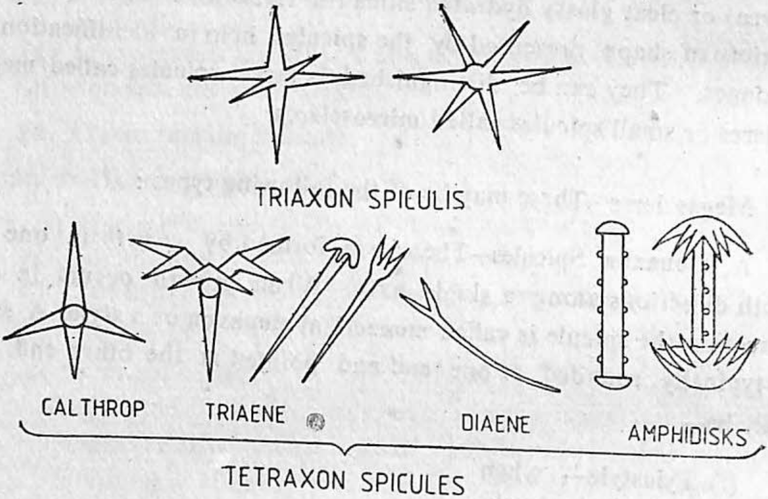


Fig. 2.2. Triaxon and tetraxon spicules

C. Tetraxon spicules—These are also called **tetractines** and quadriradiates. Each has typically 4 rays, not in the same plane. These may be :

Calthrops—when 4 rays are more or less equal.

Triaenes—when 1 ray is elongated (rhabdome), bearing 3 smaller rays (cladome). If one smaller ray is lost it becomes **diaene.**

Amphidisk—when disc occur at both ends of a rhabdome.

A triradiate spicule is the most common spicule of calcareous sponges and results by the loss of the rhabdome of a triaene.

D. Polyaxon spicules—These spicules have several equal rays radiating from a central point.

E. Spheres—These are almost round spicules in which growth takes place around a centre.

Desma is a special kind of megasclere consisting of an ordinary minute monaxon, triradiate, spicule called **crepis** on which silica is irregularly deposited.

In the beginning silica follows the crepis but later develops elaborate branches and when they are united into a network then it is called **lithistid.**

2. Microscleres— These are minute spicules scattered in mesenchyma and is also called flesh spicules. These may be curved in one plane or spirally twisted. They may be of the following types :

(i) Sigmas—C-shaped forms

(ii) Sigmaspire—spirally twisted sigmas

(iii) Toxas— bow-shaped spicules

(iv) Chelas—with recurved hooks

Asters—These may have small centres and long rays or large centre and small rays.

(i) Small centred forms include **oxyasters** with pointed rays and **strongylasters** with rounded ends.

(ii) Large centre forms include **spherasters** with definite rays and **sterrasters** with reduced small projections.

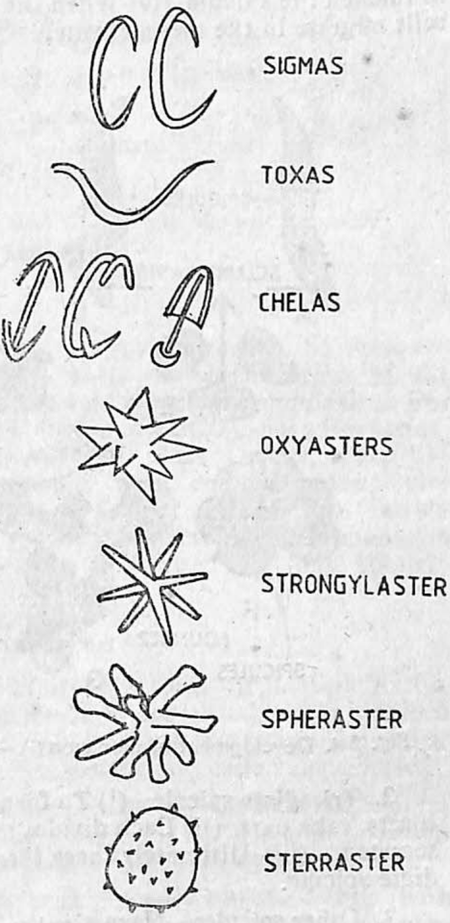


Fig. 2.3. Different types of microscleres

2.5. Development of Spicules

1. Monaxon spicules—(i) In a binucleate scleroblast a small deposition of $CaCO_3$ appears. (ii) With development the two nuclei are separated wide apart and scleroblast divides into two cells. (iii) The one lying towards inner side called **founder** gives shape and length to the spicule and the other cell lying outwards called **thickner** helps to thicken the spicule. (iv) When the spicule is fully formed both the cells migrate in the mesenchyma.

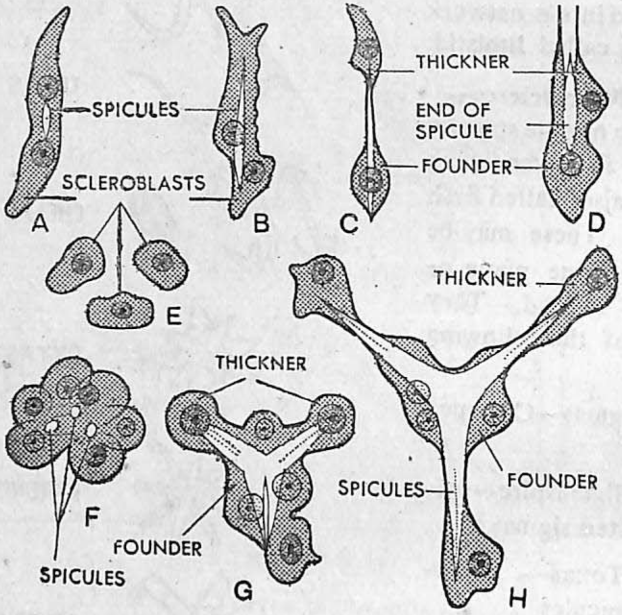


Fig. 2.4. Development of monaxon (A–D) and triradiate (E–H) spicules

2. **Triradiate spicule**—(i) To form a triradiate spicule 3-scleroblasts take part. (ii) Each divides and in each pair a small spicule is secreted. (iii) Ultimately these three spicules unite to form a triradiate spicule.

3. **Other spicules**—Hexactinal spicule is formed by the secretion of silica by a mass of multinucleate mass derived from repeated division of a silicoblast.

2.6. Spongin fibres

Siliceous spicules of many monaxonida is bound together by spongin material. The skeleton of Keratosa sponges is composed entirely of spongin fibres but often contains foreign bodies.

These are secreted by spongioblasts present in the mesenchyma. Spongioblasts arrange themselves in rows and each secretes a small spongin rod. Each of these small rods fuse with those of adjacent ones to form a long fibre which in its turn joins together to form a network of spongin fibres.

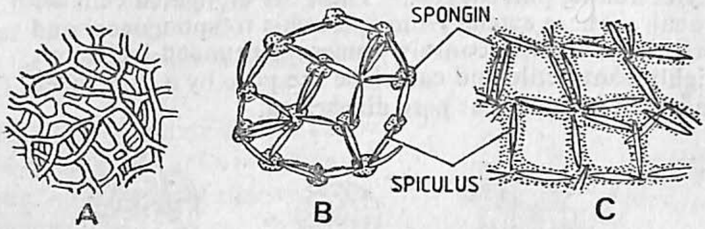


Fig. 2.5. A. Spongin fibres, B. and C. Spongin fibres with foreign particles and spicules

2.7. Importance of Spicules

The structure of spicules is constant for a species. So these are used in identification and form the basis of classification of the phylum depending on their structure and chemical composition. For example class Calcarea contains spicules of $CaCO_3$, class Hexactinellida has six-rayed siliceous spicules and class Demospongia has skeleton of spongin fibres or spongin fibres and siliceous spicules or without these spicules. This class is further divided into Tetractinellida with tetraxon siliceous spicules, Monaxonida with monaxon spicules and Keratosa whose skeleton is formed by only spongin fibres.

2.8. Histology of the Body-wall of Sponges

Sponges show cellular grade of organization. It is diploblastic. They have two embryonic layers **ectoderm** and **endoderm**. In between these layers lie **mesenchyme**. The cells of these layers are simple or modified according to their function except one called **choanocyte**.

The cells of Ectoderm—These are generally called **dermal epithelium**. They form a covering of the outer body surface and the lining of incurrent canals. The following cells form this layer :

(i) **Pinacocytes**—These are large flat, closely cemented cells with thickened central bulge containing the nucleus. They appear continuous with adjacent cells. These are generally found to cover the outer body surface when they are called **dermal epithelium**. In syconoid sponge they also line the incurrent canals and spongocoel. Whereas in leucoid sponge they line the canals and spaces found inside the body. When they line the paragastric cavity they are also called **gastral epithelium**. These cells are highly contractile and thus can reduce the surface area.

In some sponges the epidermis is formed by epitheloid membrane which is a continuous membrane having numerous scattered nuclei.

Hexactinellid sponges have no definite epidermis.

(ii) **Porocytes**—In asconoid sponges (*Leucosolenia*) there are porocytes among pinacocytes. These are elongated cells with a central canal. These extend from epidermis to spongocoel and serve as incurrent pores. They contain numerous rounded inclusions. These are highly contractile and can close the pore by a thin sheet of cytoplasm which is known as **pore diaphragm**.

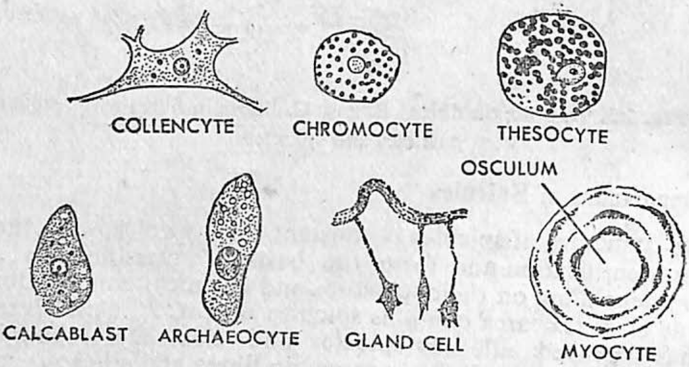


Fig. 2.6. Cells of mesenchyme

Cells present in Mesenchyma

The gelatinous, transparent matrix of mesenchyma is known as mesogloea in which are found special cells called amoebocytes which may be of the following type :

(i) **Collencytes**—These are with long, slender branched pseudopods.

(ii) **Chromocytes**—These have lobose pseudopodia and contain many spherical pigment granules.

(iii) **Thesocytes**—These are filled with food reserves.

(iv) **Scleroblasts**—These secrete skeleton. They may be **calcoblasts** (secrete calcareous spicules), **silicoblasts** (give rise to siliceous spicules) and **spongioblasts** (secrete spongin fibres).

(v) **Archaeocytes**—They have blunt pseudopodia, large nuclei, conspicuous nucleolus and cytoplasmic inclusions. They can give rise to six cells or other cells and associated with transport of food and wastes.

(vi) **Gland cells**—These are found attached by thin strands with body surface and are associated with the secretion of lime.

(vii) **Desmacytes**—These are also called fibre cells and are found arranged in layers around large internal channels (in Demospongia).

(viii) **Myocytes** (Muscle cells)—These are elongated, narrow, nucleated cells arranged around in a circular manner around osculum or other openings. By their contractibility they can control the size of the openings.

The **endoderm** is represented only by choanocytes :

(i) **Choanocytes**—These are derived from the embryonic endoderm.

These line the spongocoel of asconoid sponges (*Leucosolenia*) and in or conoid and leuconoid sponges they line radial canals (flagellated chambers).

Each is a round or oval in shape with a basally or apically situated nucleus. The base of the cell lies in mesenchyma whereas the other end has a contractile transparent **collar** encircling the base of a long flagellum. These help to produce water current inside the body.

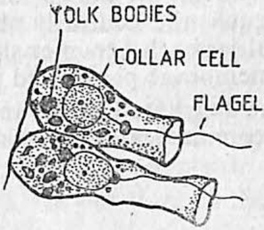


Fig. 2.7. Choanocytes

1.9. Canal System in Sponges

Canal system in sponges was discovered by **Robert E. Grant** (1925). He found that water enters in the sponges by small apertures scattered over the body surface and leaves it at a certain larger hole after traversing a fixed course. This later on came to be known as **'Canal system'**. Later workers in the same field observed different types of canal systems arising from simple forms, differing in modifications and complications. These canal systems may be classed as :

1. Ascon type,
2. Sycon type,
3. Leucon type which includes—
    A. Euryphylous type,
    B. Aphodal type,
    C. Diplodal or Rhagon type.

1. Ascon type—This is the simplest type of canal system. On the body surface are found regularly arranged many small rounded apertures called **inhalent pores** or **Ostia**. The wall is thin and these apertures open directly in the centrally placed **paragastric cavity** which opens to the outside through an opening called **Osculum**. The internal lining is formed by flagellated collared cells or choanocytes.

In Ascon type water enters into paragastric cavity through ostia and escapes to the exterior through osculum. Ex. *Clathrina.*

2. Sycon type—This type has been derived from the simple ascon type by a process of unequal growth and a consequent folding of the body-wall resulting in the formation of blind diverticula the interior of which becomes covered by collared cells. The central portion of the gastral cavity becomes lined by flattened epithelium cells.

There is a large number of regularly arranged straight passages in the thick body-wall. These passages are of two kinds : (i) **Incurrent canals** which are narrow and lined by flat epithelial cells,

(ii) **Radial** or **flagellated passages** or canals lined by flagellated collared cells or choanocytes.

The incurrent canals end blindly at their inner extremities and do not reach the centrally placed paragastric cavity. On the external extremities each becomes slightly dilated which is covered by a thin pore membrane perforated by 3-4 small openings called **ostia.**

The flagellated canals in their turn are blind at their outer ends. Each communicates internally with paragastric cavity by a short

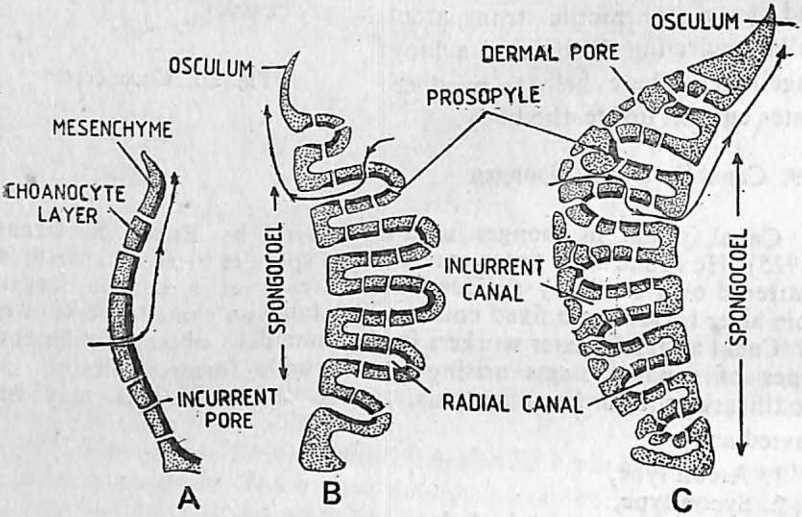


Fig. 2.8. A. Ascon type; B. folding of body-wall and C. Syconoid type

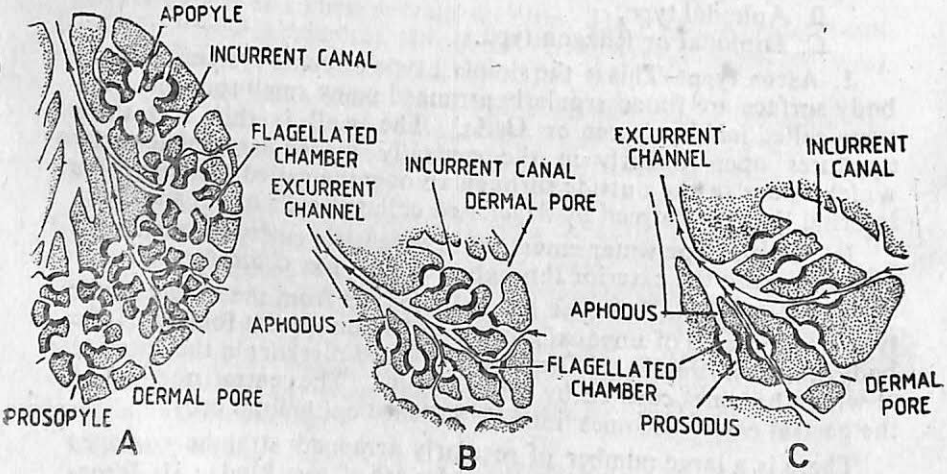


Fig. 2.9. Canal system in sponges : A. Euryphylous type; B. Aphodal type; C. Diplodal type

but wide passage called excurrent canal which is lined by flat epithelium cells like incurrent canal and paragastric cavity.

The incurrent and radial canals lie side by side and communicates with each other by small apertures called **prosopyles.**

Water enters through ostia into incurrent canals and then through prosopyles enters the radial canals due to flagellar movement of flagellated collar cells. Water then enters the paragastric cavity through excurrent canal and ultimately passes out through the large osculum. Ex. *Sycon.*

3. Leucon type—Radial canals of the sycon type of canal system may be compared with ascon like canal system. If this undergoes the same process of folding by which sycon type was derived from ascon type then this gives rise to leucon type of canal system. Due to this growth and folding the radial canals get arranged in groups. Each group being centered around a main excurrent canal. The incurrent canals may form a branching system. This results in the reduction of flagellated chambers and ultimately the chambers become small and spherical and irregularly scattered in the sponge wall.

(a) **Euryphylous type**— In this case the sponge has a flat broad base having an opening at the apex and looks like a pyramid. There are a number of flagellated chambers (radial canals) in the upper wall into which the prosopyles open. The lower basal wall is without flagellated chambers and is known as **hypophore** whereas the upper wall with flagellated chambers is called **spongophore**. The folded spongophore give rise to incurrent canals. Due to this folding the flagellated chambers do not open into the gastral cavity but into the diverticula of it which are the excurrent canals.

(b) **Aphodal type**—In this type of canal system the flagellated chambers do not open into the excurrent canals directly but are removed from the excurrent canals by prolongations of apopyles into small canals called **aphodus** which are lined by the prolongation of the epithelium of excurrent canals into which they open. There is only one prosopyle to each chamber.

(c) **Diplodal type**—In this type incurrent canals do not open directly into flagellated canals but open by narrow canals called **prosodus** which are prolongations of prosopyles. Thus each flagellated chamber has a **prosodus** leading to incurrent canals and an **aphodus** leading from it to excurrent canals.

2.10. Mechanism of current production

To produce an incurrent and excurrent condition there are two factors which are essential :

(i) For entering water through ostia into the body there must be a pressure within it less than that in the incurrent canals.

(ii) For escaping water through osculum there must be a pressure within chambers higher than that in the excurrent canals.

But as the pressure in the incurrent and excurrent canals are the same, there must be a difference of pressure within the chamber itself and the lower pressure must be towards the periphery. Such a distribution of pressure is set up when each flagellum causes a flow of water towards the centre of the chamber.

The requisition of a good Canal

(i) High oscular velocity for rapid removal of waste products;

(ii) a slow current without eddies in flagellated chambers for helping choanocytes to pick up food particles;

(iii) small area of choanocytes and consequent small expenditure of energy for current production.

2.11. Reproduction in Sponges

Sponges reproduce by the following methods :

1. Asexual reproduction includes—

(a) Budding

(b) Reduction bodies and

(c) Gemmules.

2. Sexual reproduction by the formation of ova and sperm.

3. Sponges have high power of regeneration.

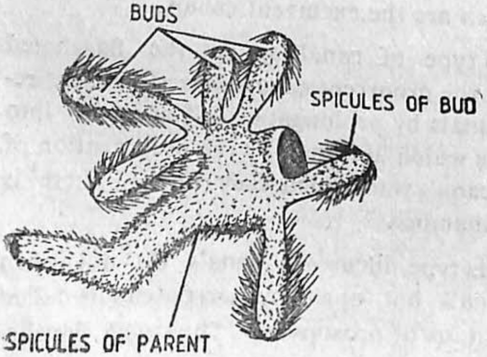


Fig. 2.10. Budding

1. Asexual reproduction :

(a) **Budding**—Sometimes form the attached end or stolon new outgrowths come out which slowly form new individuals. These may break or may remain attached with the parent body forming a large colony. Ex. *Leucosolenia, Tethya.*

(b) **Reduction bodies**—During unfavourable condition sponges disintegrate and form many reduction bodies. One such body is formed by a group of **amoebocytes** covered by **epidermis.** When the condition is favourable these bodies can give rise to new individuals.

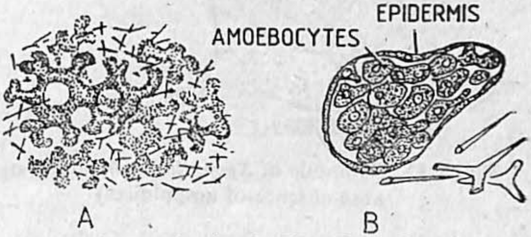


Fig. 2.11. A. reduction bodies; B. section through such a body

(c) **Gemmules**—These are formed during extreme condition to tide over the adverse condition of life.

In fresh-water sponges gemmules are formed as follows :

(i) Group of archaeocytes becomes covered by amoebocytes.

(ii) Amoebocytes secrete an **inner** and an **outer membrane.**

(iii) Scleroblasts form **amphidisc spicules** which get arranged radially between the two membranes (amphidiscs are absent in gemmules of fresh-water sponge, *Spongilla,* fig. 2.13).

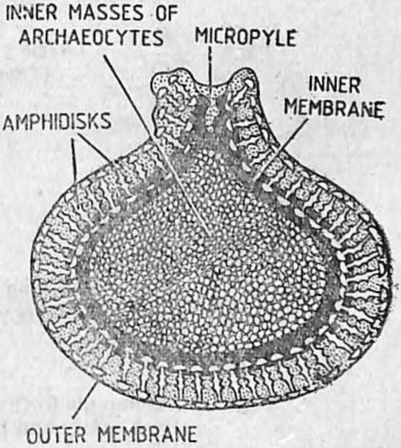


Fig. 2.12. A complete gemmule

The parent disintegrates and these gemmules become free. They pass over unfavourable condition and during favourable condition the inner cell mass migrate out through

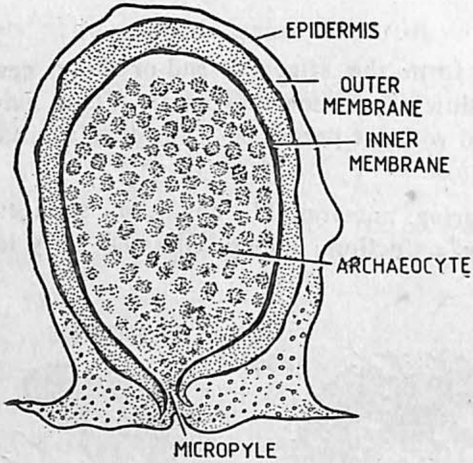


Fig. 2.13. Gemmule of *Spongilla* at hatching stage (note absence of amphidiscs)

the aperture of gemmule called **micropyle** and slowly organise into a new sponge.

The formation of gemmule ensures the continuance of the species (survival) and dispersal (by wind).

In **marine sponges** (Demospongia) gemmules originate as a group of archaeocytes covered by thin membrane (Fig. 2.14) formed by flat ciliated cells. The cilia are absent at the posterior end.

When these become free from the parent body, they swim for sometime and then get attached to the substratum by non-flagellated posterior end. They loose cilia and slowly organise into a new young sponge.

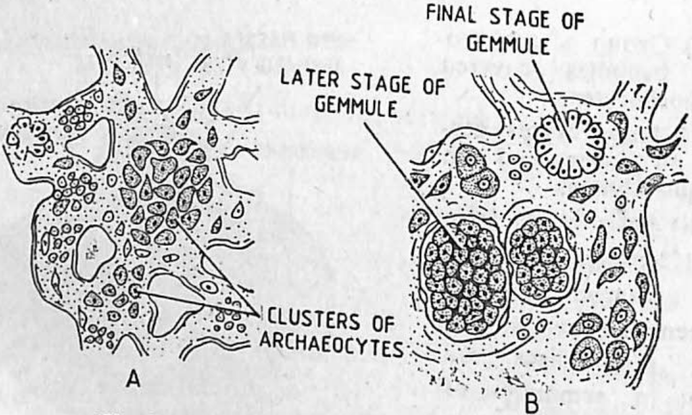


Fig. 2.14. Gemmule formation in marine sponge : A. early and B. later stages

2. Sexual reproduction :

Sponges are either dioecious (sexes are separate) or monoecious (hermaphrodite). They produce sperms and ova for sexual reproduction.

In male the sperm mother cell (spermatogonia) called spermatogonium is found in mesenchyma. This becomes covered by **cover cell** and divides to form small cells called **spermatocytes** which form sperms. Each sperm has a distinct head and a vibratile tail.

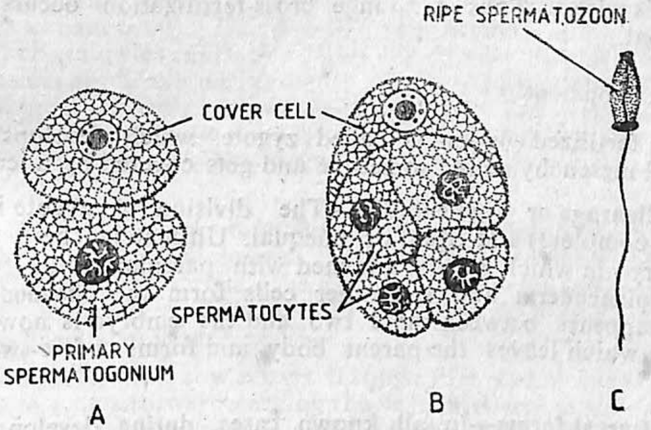


Fig. 2.15. Formation of Sperms

In female the **ovocyte** or oogonium is formed from archaeocyte. This divides by meiosis and forms a large spherical **ovum**.

Fertilization—Sperms of one sponge is carried by water current

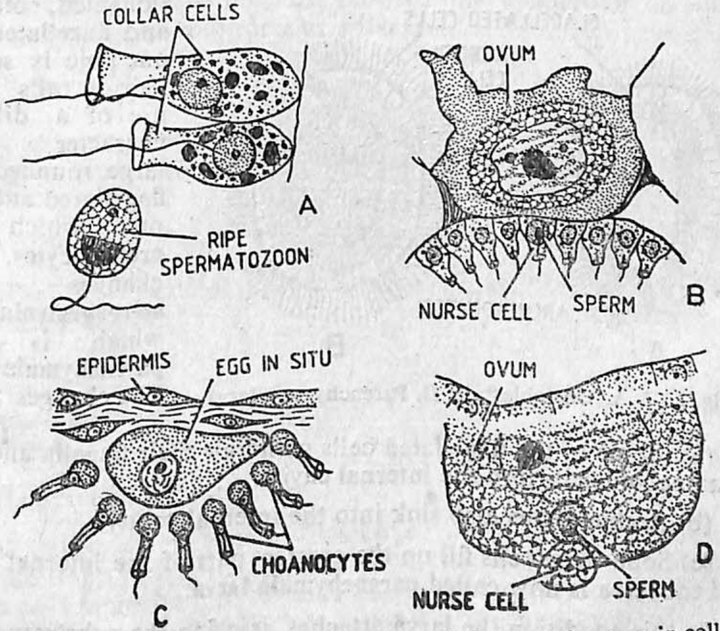


Fig. 2.16. A. Mature sperm near collar cells; B. Ovum and sperms in collar cell; C. Nurse cell transferring sperm into ovum; D. Fertilized egg

outside the body and enters into another sponge of the same species with incurrent water. This directly fuses with the ovum or get attached with a choanocyte lying near the ovum. The choanocyte with the sperm fuses with the ovum and set free the sperm which then fuses with it. Thus in sponge cross-fertilization occurs which is internal.

2.12. Development

The fertilized ovum is called **zygote** which develops in the parental mesenchyme for sometime and gets covered by a capsule.

(i) Cleavage or segmentation—The division of zygote is holoblastic (complete) and equal or unequal. Ultimately there appears an embryo in which 8 cells attached with parental tissue form the future **pinacoderm** and the other cells form the **choanoderm**. A cavity appears between these two and the embryo is now called **blastula** which leaves the parent body and forms a free-swimming larva.

(ii) Larval forms—In all known cases, during development of embryo a free-swimming ciliated larva appears but the form assumed by the larva differs in different sponges.

In case of *Clathrina* and *Leucosolenia* oval blastula changes to **coeloblastula**. This has a single layer of cells, all alike in kind—elongated, columnar and flagellated. At one pole is seen a pair of cells which are of a different character being large, rounded non-flagellated and granular which form **archaeocytes**. This changes into **stereogastrula larva** which is called **parenchymula larva**. The changes are—

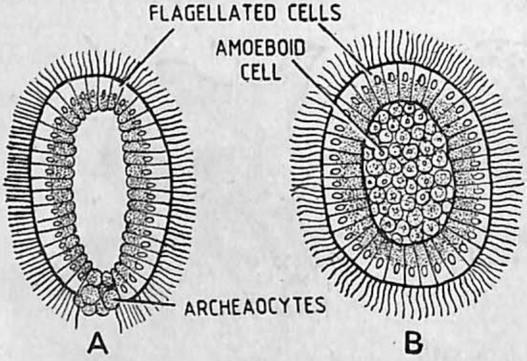


Fig. 2.17. A. Coeloblastula; B. Parenchymula larva

(a) Some of the flagellated cells withdraw their flagella and pass as amoeboid cells into the internal cavity.

(b) Archaeocytes also sink into the internal cavity.

(c) Soon these cells fill up the greater part of the internal cavity and the larva is now called **parenchymula larva**.

In this condition the larva attaches itself to the substratum and develops into adult form. Most of the amoeboid cells now migrate to the outside to form the dermal epithelium. The flagellated cells become internal and form the choanocytes. Ostia, osculum, spicules and spongocoel are formed and it attains this young stage.

In some other sponges like *Sycon* and *Grantia* the zygote undergoes holoblastic cleavage and at 16-cell stage get fixed with the maternal choanocytes. The 8-cells (megameres) attached with maternal choanocytes represent future epidermis and other 8-cells (micromeres) are future choanocytes which divide repeatedly and acquire flagella on inner side facing blastocoel. The megameres or future epidermal cells are large and round cells at the centre of which arises a mouth. This stage of the embryo is called **stomoblastula.**

The next process is **inversion** of stomoblastula resulting in a typical larva called **amphiblastula.** During inversion the embryo turns completely inside out through the mouth. Due to this the flagellated cells form the anterior half and the posterior half is formed by large non-flagellated granular cells.

The amphiblastula now passes through the radial canal to the outside and swims forward keeping the flagellated end at the anterior. During this time gastrulation occurs by **invagination** of the flagellated part into the non-flagellated macromere cells.

The gastrula then attaches itself to some substratum. It develops the central spongocoel, ostia all over its body and the large opening osculum at the free-end. It now looks like young sponge and is called **olynthus** or asconoid stage. Slowly radial canals develop and it is changed to a syconoid form or adult stage.

3. Regeneration :

Sponges have peculiar power of regeneration. Even if the body is cut into many small pieces each part will regenerate the lost part.

An Example of Calcareous Sponge : *Scypha* :

2.13. The new name of *Sycon* is *Scypha*. It has the following systematic position :

Phylum—Porifera
Class—Calcarea
Order—Heterocoela
Genus—*Scypha* or *Sycon*

2.14. Habits and Habitat

It is a grey to light brown calcareous sponge found attached to some substratum or rock near shallow sea-shore. It is a colonial sponge as it branches into several cylindrical structures attached to the substratum or stolon. Each is about 2·5 to 8·5 cm long.

2.15. External features

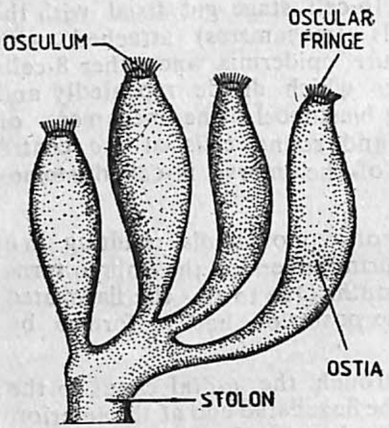


Fig. 2.18. *Sycon*

The body of *Scypha* is a hollow flexible branching cylinder attached to substratum. To naked eye the surface appears smooth but with lens innumerable polygonal elevated areas appear which are separated by grooves. In each groove is a minute pore called **ostia or inhalent pore** through which water enters into the body. At the free end of each cylinder is a prominent aperture called **osculum** or **exhalent aperture** through which water leaves the body. This is surrounded by a circle of large monaxon spicules of $CaCO_3$ forming **oscular fringe**. The entire body surface is also provided with numerous monaxon spicules due to which the body appears rough when touched by hand. The lumen of the *Scypha* is called **spongocoel** or **paragastric cavity** which opens to outside by osculum.

2.16. Body-wall

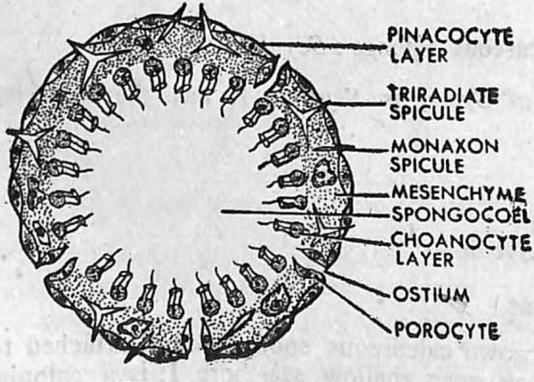


Fig. 2.19. T. S. of the body

The *Scypha* is a diploblastic animal. The outer layer is formed by **epidermis** (ectoderm) consisting of pinacocytes and inner layer is the **endodermis** consisting of choanocytes. Between these two layers is found the gelatinous matrix of **mesenchyme** containing spicules and different types of amoeboid cells (amoebocytes).

Epidermis

(a) **Pinacocytes**—These are large, flat, nucleated and contractile cells lining the body surface, incurrent canal, excurrent canal and paragastric cavity. The pinacocytes which line the body surface and incurrent canals are called **dermal epithelium** and those lining the excurrent canal and paragastric cavity are called **gastral epithelium**. As these are contractile in nature, they can expand and contract the body surface.

(b) **Porocytes**—These are tubular with a canal and are found between pinacocytes. Through these cells incurrent canal opens into radial canal.

Endodermis

Choanocytes—These are restricted only in the radial or flagellated chambers. These are oval or round with broad base in the mesenchyme containing nucleus and vacuoles. The free end is provided with a transparent **collar** surrounding a long **flagellum.** The flagellum help to bring in water and indirectly the choanocytes help in digestion, excretion and reproduction of *Scypha*.

Mesenchyme

A. Amoebocytes : These are irregular like amoeba found in the matrix of mesenchyme and are of many kinds—

(a) **Collencytes**—These are small with long branched pseudopodia which unite to form a network.

(b) **Chromocyte**—These are with lobose pseudopodia and contain pigment granules.

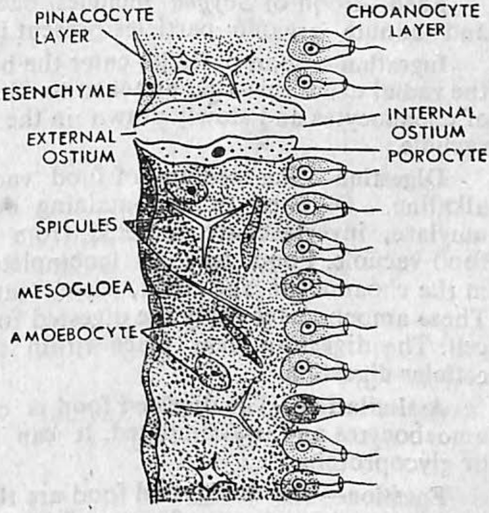


Fig. 2.20. A portion of body-wall

(c) **Thesocytes**—These are with blunt pseudopodia and contain reserve food materials.

(d) **Scleroblasts**—These are associated with the secretion of spicules and on the nature of the substance secreted they are called—

(i) **Calcoblasts**—These secrete calcareous spicules.
(ii) **Silicoblasts**—These form spicules with silica.
(iii) **Spongioblasts**—These form skeleton of spongin fibres.

(e) **Archaeocytes**—These are undifferentiated embryonic cells which take part in regeneration, formation of germ cells or other type of cells and convey food from one place to another place. The nucleolus within nucleus is very prominent.

(f) **Myocytes**—These are contractile and are arranged in circles round osculum or other apertures. These control the closing and opening of these apertures.

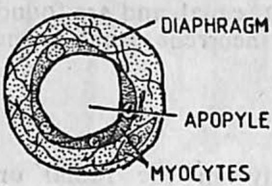


Fig. 2.21. Myocytes around apopyle

(g) **Gland cells**—These secrete lime and are attached to the body surface by long strands.

2.17. Nutrition in Scypha

Food—Food of *Scypha* includes bacteria, protozoans, diatoms and minute organic particles present in the surrounding water.

Ingestion—Food particles enter the body with incurrent water. In the radial canal these get attached to the outer surface of the **collar** of choanocytes and slowly drawn in the cytoplasm forming a food vacuole.

Digestion—The medium of food vacuole is first acidic and then alkaline. Digested juice containing enzymes like trypsin, lipase, amylase, invertase are secreted from cytoplasm and poured into food vacuole. Food may be incompletely or completely digested in the choanocyte and then passed into wandering amoebocytes. These amoebocytes carry the digested food from one cell to another cell. The digestion takes place within the cell so it is called **intracellular digestion.**

Assimilation—The digested food is conveyed to different cells by amoebocytes and is assimilated. It can be stored as fat, glycogen or glycoprotein.

Egestion—The undigested food are thrown away by amoebocytes in the outgoing current of water which carry them to the outside.

2.18. Canal system in Sycon

The most vital role in the physiology of *Sycon* is played by the feeding water current on which their life depends. All the exchanges between the sponge body and external medium are maintained by means of this current. Food and O_2 brought into the body and excreta and reproductive bodies are carried outside. The current is caused by the flagella of the collar cells. Inside the body, the water current flows through a certain system of spaces forming the canal system. In *Sycon* the canal system is syconoid type and is formed by the following canals and spaces :

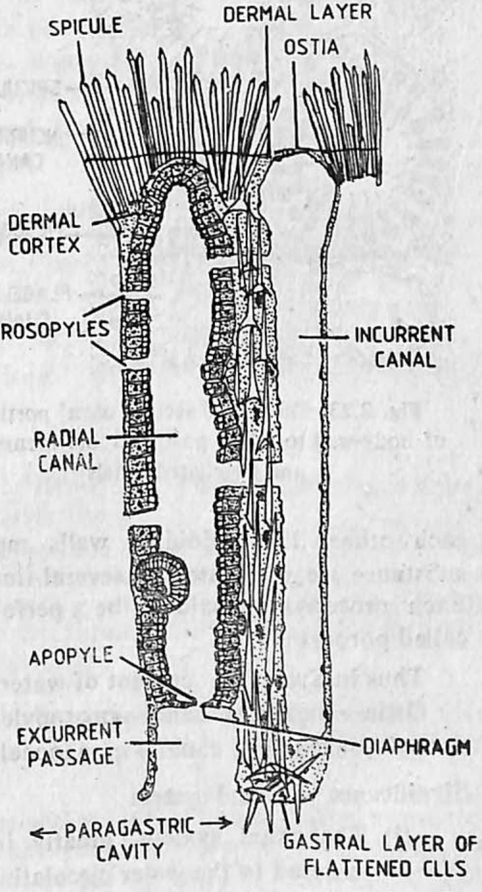


Fig. 2.22. Sectional view of the body-wall of *Sycon* to show canal system (diagrammatic)

A. Spongocoel—In the centre of the body of *Sycon* is a spacious space called paragastric cavity or spongocoel. It starts from the base and ends at the tip of the body where it opens to the outside by a large opening called Osculum.

B. Flagellated canals—Around the spongocoel the body-wall contains many regularly spaced, straight elongated finger-like radial canals. These canals are lined by flagellated collared cells or choanocytes. Therefore these canals are called flagellated canals. Outer end of each of these canals terminate blindly just below the polygonal elevation of the outer body surface. The inner surface of each communicates with an excurrent canal.

C. Excurrent canal—It is a short but wide canal leading from the radial canal to the spongocoel. It is lined by flat, ectodermal cells. The outer end of the excurrent canal is separated from the flagellated chamber by a thin diaphragm. This diaphragm is perforated centrally by a large rounded aperture called apopyle. This aperture can be contracted or expanded.

D. Incurrent canals—In between the flagellated canals lie narrow spaces called incurrent canals. They differ from flagellated canals in being lined by flattened ectodermal cells.

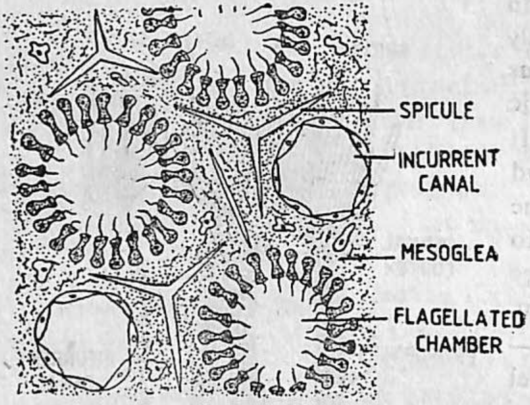


Fig. 2.23. Tangential section of a portion of body-wall to show positions of incurrent and flagellated canals

The inner ends of incurrent canals terminate blindly without reaching the spongocoel. The outer ends are somewhat oval and are closed by thin pore membrane which is pierced by two or three minute apertures called the Ostia.

The flagellated and incurrent canals lie side by side parallel to and alternating with each other. The adjoining walls made of thin layers by sponge substance are perforated by several tiny openings, called prosopyles. Each prosopyle is said to be a perforation in a single tubular cell called porocyte.

Thus in *Sycon* the current of water flows in the following way : Ostia→Incurrent canal→prosopyle→ flagellated (radial) canal→ apopyle→excurrent canal→spongocoel→ostium→outside.

Significance of Canal system

(i) The canal system greatly increases the internal surface exposed to the water circulating in the body of the sponge. Thus aiding in respiration.

(ii) Incoming water brings O_2 for respiration and food material for the animal.

(iii) Outgoing water takes away CO_2 and other excretory matter to the outside.

2.19. Reproduction in Sycon

Sycon reproduces both asexually and sexually.

2.20. Asexual reproduction takes place by (i) Budding, (ii) Regeneration and (iii) Gemmules.

(i) Budding—*Sycon* reproduces by budding during favourable condition. A small outgrowth comes out near the attached end which gradually increases in size and finally detach from the parent to lead an independent life. Sometimes several buds remain attached with the parent body and thus increase the size of the *Sycon*.

(ii) Regeneration—*Sycon* has high power of regeneration. A small part of the body can slowly form a complete *Sycon*.

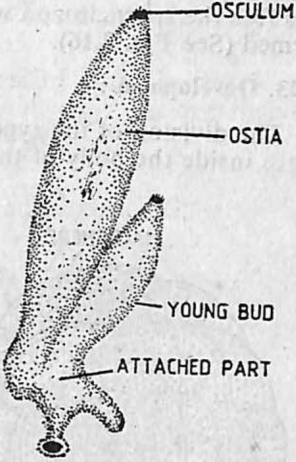


Fig. 2.24. Budding in *Sycon*

(iii) Gemmule—First of all a group of archaeocytes form a spherical structure. This gets surrounded by a thin inner and an outer thick membrane. Amphidisc spicules are attached with the outer membrane which protect the inner archaeocytes. At one end is an opening called micropyle. These gemmules are freed when the *Sycon* disintegrates during unfavourable condition. During spring the archaeocytes come out through micropyle and reorganise to form a new *Sycon*. (See Fig. 2.12)

2.21. **Sexual reproduction** in *Sycon* occurs by sperms and ova which are formed in the mesenchyme of the same individual from the archaeocytes.

(i) **Spermatogenesis** —The sperm mother cell is called **spermatogonium** which is a large archaeocyte. This becomes surrounded by one or more **cover cells** formed by the division of spermatogonium or other archaeocytes. This is called **spermatocyst.** Then the spermatogonium divides 2-3 times and each cell develops into a sperm. A mature sperm has a nucleated **head** and a long vibratile **tail** (See Fig. 2.15).

(ii) Orgenesis—The egg mother cell called **ovocyte** develops from a large archaeocyte. It contains a distinct nucleus with a **nucleolus**. It receives nourishment from special choanocyte called **trophocyte** or **nurse cell**. When full grown then the nucleus divides by meiosis and a large **ovum** is formed which projects into the radial canal.

2.22. Fertilization.

Fertilization is internal and in *Sycon* cross-fertilization occurs. Sperms of one *Sycon* enter into radial canal of the other along with incurrent water. Here the sperm enters the nurse cell or a choanocyte. This becomes amoeboid, fuses with the ovum and sets free the spermatozoa which fuses with the ovum and a zygote is formed (See Fig. 2.16).

2.23. Developmen :

The division of the zygote in **holoblastic.** The development takes place inside the body of the *Sycon.*

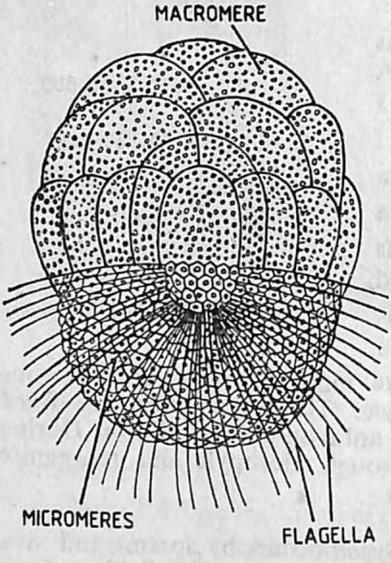


Fig. 2.25. Amphiblastuala larva

(i) The first 3 divisions are vertical which produces a pyramidal structure of eight cells.

(ii) The fourth division is horizontal forming 8 upper smaller **micromeres** and 8 larger **macromeres.**

(iii) Then a cavity a appears in between them and the embryo is called **a blastula.**

(iv) The micromeres divide rapidly and macromeres become round and granular. This stage is called **stomoblastula.**

(v) The micromeres or stomoblastula acquire flagella on the inner ends. Later on due to inversion flagellated ends become external. This flagellated larva is called **amphiblastula** larva. It leaves the body with excurrent water and leads a free-swimming life. Later on it undergoes gastrulation to form the gastrula.

(vi) Then flagellated cells migrate into blastocoel and get covered by rapidly dividing granular macromeres. This is called invagination and emboly. This is the gastrula stage which has an outer layer of ectoderm formed by macromeres and an inner layer of endoderm formed by flagellated cells. It opens to outside by **blastopore.**

(vii) The gastrula then attaches to some substratum by blastopore end and undergoes metamorphosis. The changes are as follows :

(a) It elongates and becomes cylindrical. An opening called osculum is formed at distal end.

(b) The non-flagellated cells modify into pinocytes and dermal epithelium and gastral epithelium.

(c) The flagellated cells transform into choanocytes and line the radial canals.

(d) Mesenchyme with its cells are formed by both the layers.

(e) Ostia appear on body-wall. The larva now reaches olynthus stage which slowly transforms into young Sycon.

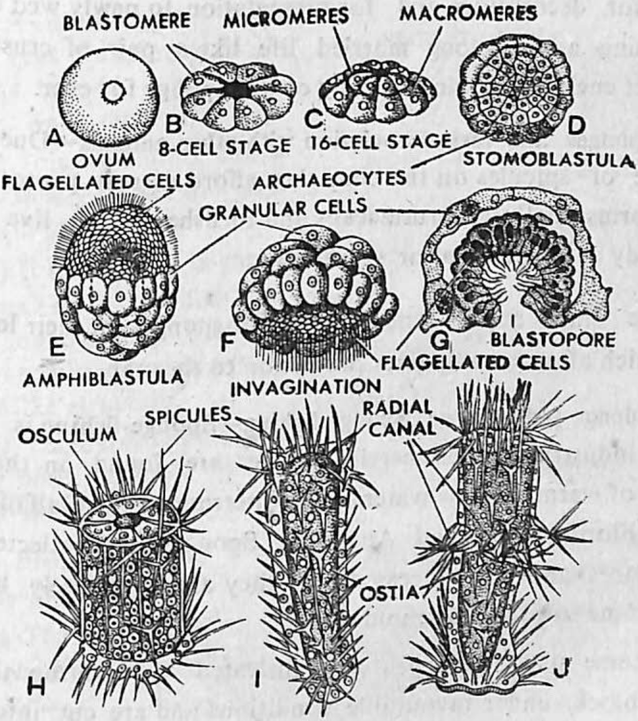


Fig. 2.26. Different stages of development in *Sycon*

2.24. Economic Importance of Sponges

Sponges are known to man from ancient times and these have the following economic importances :

1. Sponges and Man—Sponges are used by man for various purposes. The ancient Greeks used the dried fibrous skeletons for washing, bathing or for cleaning their furniture. Greeks used them as paint-brushes. As sponges can hold liquid they are also used as cups. Sponges are also used now-a-days for clearing walls, floors and ceilings of houses, for cleaning cars, furniture and for polishing purposes. They can be used as pads in special clothings and as a packing material for sensitive instruments.

2. Sponges as Food—It is rarely used as food due to their smell and hard spicules. Some parasitic crustaceans feed on their tissues.

3. Sponges for Decoration and Presentation—Many people use certain glassy, transparent sponges (*Hyalonema*) for decoration purposes. Venus's-flower-basket is a beautiful sponge. It (*Euplectella*) is used for decoration and for presentation to newly wed couples symbolising a happy long married life like a pair of crustaceans which get enclosed within the body of this sponge for ever.

4. Sponges and their association with other animals—Due to the presence of spicules on the body they afford a great protection to some worms, molluscs, crustaceans and to fishes which live within their body as commensal or symbionts.

Some crabs attach small pieces of sponges on their legs and shell which after growth gives protection to the crab.

5. Sponge Industry or Sponge-fishing—Sponge-fishing is an important industry. The commercial sponges are found on the rocky bottom of warm shallow waters of Mediterranean, the Gulf of Mexico off the Florida coast and Australia. Sponges are collected from these places and are processed until they are completely bleached and become soft for household use.

At some places sponges are cultivated by planting them on cement blocks under favourable conditions and are cut into pieces to be sold in the market.

6. Harmful Sponges—Sponges are not only useful to mankind but there are some sponges which are harmful to us. The boring sponge *Cliona* bore the shells of the oysters and barnacles and break them into pieces resulting their death. Some sponges produce poisonous secretions and when touched the skin is pricked by the poisonous spicules producing itching of the skin.

2.25. Some Important Sponges

2.26. Euplectella

Classification :
Phylum—Porifera
Class—Hexactinellida
Order—Hexasterophora
Genus—*Euplectella*
Species—*E. aspergillum*

(i) It is a deep sea form found near Philippine islands and has become curved due to slow water current.

(ii) It is commonly called **Venus' flower basket** and is a beautiful glass sponge.

(iii) It is made of six-rayed siliclous spicules which are held together by siliceous cement resulting in a beautiful basket-like structure.

(iv) The curved upper end of the body is closed by an **oscular sieve.**

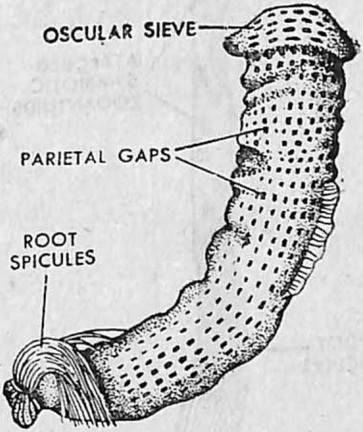


Fig. 2.27. *Euplectella*

(v) From the base arise root spicules which are long siliceous threads which fasten the sponge to its unstable slimy substratum.

(vi) The spongocoel contains a pair of crustacea (*Spongicola*) which had commensal life throughout their life. For this reason *Euplectella* is a beautiful presentation for newly married couple in some countries.

2.27. Hyalonema

Classification :
Phylum—Porifera
Class—Hexactinellida
Order—Amphidiscophora
Genus—*Hyalonema*

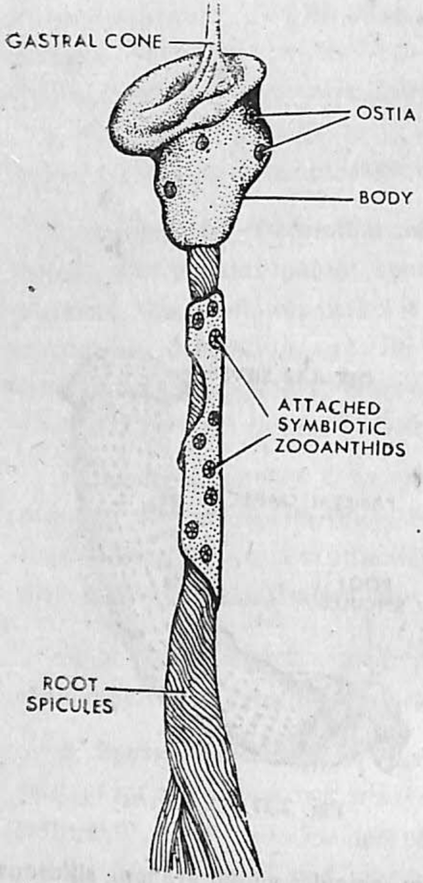


Fig. 2.28. *Hyalonema*

(i) *Hyalonema* is commonly called **glass-rope sponge.**

(ii) It is found in seas and the body is long reaching about 40 cm.

(iii) It is generally found in close association with some zooanthid leading a symbiotic life.

(iv) The main body is oval or round bearing a conical **gastral cone**. From this project a bundle of long **root spicules** which are held together by siliceous secretion. This is used for attachment.

2.28. Oscarella

Classification :

Phylum—Porifera

Class—Demospongia

Sub-class—Tetractinellida

Order—Myxospongida

Genus—*Oscarella*

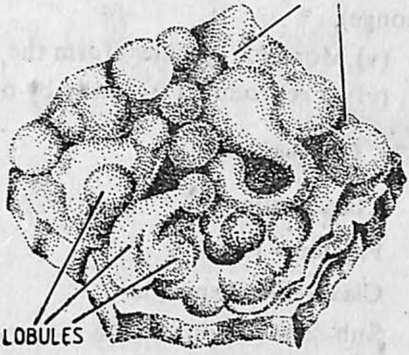


Fig. 2.29. *Oscarella*

(i) It is a bright coloured small sponge whose upper surface is lobulated.

(ii) The basal part is filled with eggs and embryos and the peripheral part contains the canal system which is of leuconoid type.

(iii) Each lobule contains an excurrent canal surrounded by flagellated chambers and the depressions between the lobules house the incurrent channels.

(iv) It is without any skeleton.

2.29. Cliona

Classification :

Phylum–Porifera
Class—Demospongia
Order—Monaxonida
Sub-order—Hadromerina
Genus—*Cliona*

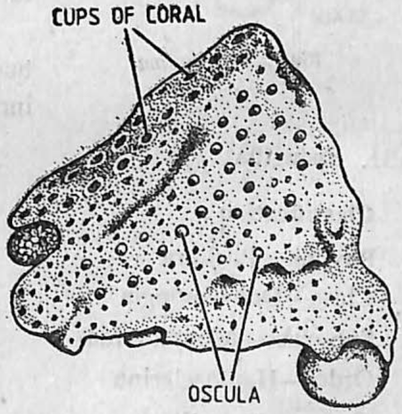


Fig. 2.30. *Cliona*

(i) *Cliona* is commonly called **'Boring sponge'** or **'Sulphur sponge'**.

(ii) It is marine and found abundantly along Atlantic coast.

(iii) At young stage it generally burrows in the shell of oysters and other bivalves by secreting acid for protection.

(iv) Within the channel formed by boring it grows to a mass of

15-20 cm, becoming sulphur yellow in colour (so called sulphur sponge).

(v) Monaxon spicules form the skeleton.

(vi) It reproduces sexually by ova and sperms.

2.30. Chalina

Classification :

Phylum—Porifera
Class—Demospongia
Sub-class—Monaxonida
Order—Haplosclerina
Genus—*Chalina*

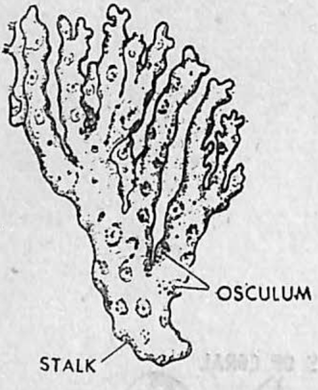


Fig. 2.31. *Chalina*

(i) *Chalina* is commonly called **Dead man's finger** found in deep water, orange-brown or red in colour.

(ii) It is much branched and each branch looks like a finger, so also called **mermaid's glove.**

(iii) Each branch is perforated by numerous openings or **oscula.**

(iv) Monaxon siliceous spicules embedded is spongin fibres constitute the skeleton of this animal.

(v) Asexual reproduction by budding and sexual reproduction includes a free-swimming larva.

2.31. Spongilla

Classification :

Phylum—Porifera
Class—Demospongia
Sub-class—Monaxonida
Order—Haplosclerina
Genus—*Spongilla*

(i) *Spongilla* is a fresh-water sponge found attached to submerged sticks and plants of ponds, lakes and streams.

(ii) It is cosmopolitan in its distribution.

(iii) Siliceous spicules form the skeleton.

(iv) Canal system rhagon type.

(v) Highly branched colony with numerous **oscula.**

(vi) Asexual reproduction by budding and gemmule formation; sexual reproduction also occurs.

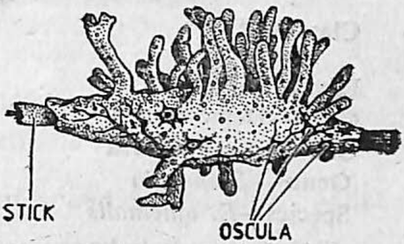


Fig. 2.32. *Spongilla*

2.32. Proterion

Classification :

Phylum—Porifera
Class—Demospongia
Sub-class—Monaxonida
Order—Haplosclerina
Genus—*Proterion*
Species— *Proterion neptuni*

(i) It is popularly called **Neptune's goblet.**

(ii) It is found in deep sea.

(iii) The shape is like a cup with a **base** and a large cup-like body.

(iv) The skeleton is formed by monaxon spicules.

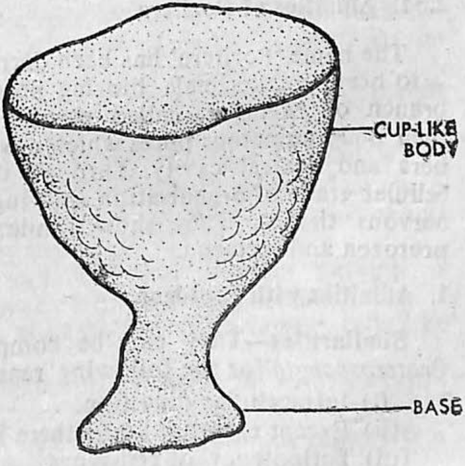


Fig. 2.33. *Proterion*

2.33. Euspongia

Classification :

Phylum—Porifera
Class—Demospongia
Sub-class—Keratosa
Genus—*Euspongia*
Species—*E. officinalis*

(i) It is popularly known as **Bath-sponge.**

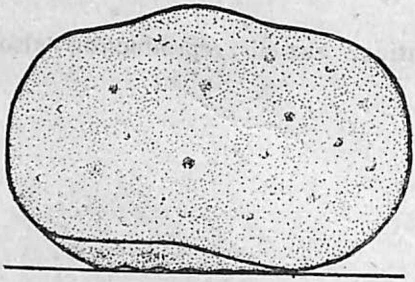


Fig. 2.34. *Euspongia*

(ii) It is found in warm shallow waters with rocky bottom and is most abundant in the Mediterranean Gulf of Mexico, Caribbean and adjacent waters.

(iii) Body is large and globular with many large and small oscula. Inside the body are different canals and the skeleton is formed by network of spongin fibres only.

(iv) These are collected by 'hooking' with a long fork at the end of a long pole and are left in shallow water until the flesh has decayed. Then they are squeezed and washed until only the horny skeleton remains. They are then bleached and ready for household use which have only spongin fibres as their skeleton.

2.34. Affinities of Porifera

The name 'Porifera' has been derived from *poros* = pore and *fera* = to bear, i.e. animals bearing pores on body. Sponges form a branch of Metazoa, called **parazoa** (Sollas, 1884). They bear on their body numerous pores which are connected with canals, chambers and central cavity. Through these water flows. They show cellular grade of organisation showing the absence of organs and nervous tissues. They show similarities and dissimilarities with protozoa and metazoa.

1. Affinities with Protozoa

Similarities—They can be compared with colonial protozoa *Proterospongia* for the following reasons—

(i) Intracellular digestion.
(ii) Except external lining there is lack of formed tissue.
(iii) Totipotency of cell-types.

(iv) Formation of skeletal spicules by single or group of cells.

(v) Both have collared (choanocytes) and amoeboid cells.

Dissimilarities :

(i) Sponges have canal system.

(ii) Sponges possess spicules of different shape and size.

(iii) Sponges develop from a fertilized egg and development of germ layers.

(iv) There is cellular differentiation and division of labour like metazoan animals.

2. Affinities with Metazoa

Similarities :

There are some similarities between the porifera and multicellular **coelenterate**. These are—

(i) Sedentary habitat.

(ii) Both are diploblastic and acoelomata.

(iii) Absence of cellular mesoderm.

(iv) The central cavity of sponge, spongocoel opens to outside by osculum whereas the central cavity of coelenterata, **coelenteron,** opens by mouth to outside.

(v) Both can reproduce asexually by budding.

(vi) Parenchymula larva of sponge resembles the planula larva of coelenterata.

(vii) Same nucleic and amino acids are present.

(viii) Gastrula show radial symmetry.

Dissimilarities :

However sponges differ considerably from **coelenterata** or other **metazoa** by the following characters :

(i) Sponge cells are less specialized and interdependent than the metazoan cells. Sponge cells are generally found isolated in the jelly-like mesenchyma.

(ii) In sponges tissue formation is restricted in surface epithelial lining. Organs like higher animals are absent.

(iii) Sponges are diploblastic but metazoans are triploblastic.

(iv) Presence of inhalent ostia on body surface, water canals in body-wall, presence of flagellated collared cells in flagellated chambers are peculiar characters of sponges.

(v) The main opening of sponge is the osculum serving as exhalent opening but in metazoa the main opening is inhalent.

(vi) Sponges do not possess **nematoblasts** or **stinging cells** like coelenterata.

(vii) No distinct digestic canals and mouth as in many metazoa and the digestion resembles protoza being intracellular.

(viii) Sponges do not have an anterior end and nervous system for coordination of different physiological functions.

(ix) In sponges during gastrulation the animal half invaginates but in metazoa it is the vegetal half.

(x) During larval metamorphosis the outer epithelial layer becomes the inner choanocyte layer whereas the inner cell layer becomes external to perform their function of epidermis and mesenchyme. This reversal of germ layers is unknown in metazoa.

2.35. Systematic Position of Sponges

Previously there were attempts to classify sponges with protozoa but this was rejected when the workers in this field recognised the germ layers in a developing sponge and the peculiarities of these germ layers were enough to separate them from metazoa was a necessary. As such where sponges are to be placed ? A suitable suggestion was given by **Sollas** who proposed a new sub-kingdom **Parazoa** for sponges. These were due to the following characteristics of sponges and was considered the main features of **Parazoa** :

(i) Absence of definite tissues or tissue layers and naturally there is no organs or organ system. This is due to the loose assemblage of cells.

(ii) Absence of any kind of symmetry.

(iii) Absence of a true alimentary canal.

(iv) Inhalent pores are ostia and internal cavities are water canals.

(v) Special type of collared flagellated cells called choanocytes are present. Spicules act as skeletal structures.

(vi) Ingoing and outgoing water serves as nutrition, respiration and excretion; this also helps in reproductive activities like carrying sperms and in fertilization.

(vii) Sponges possess high power of regeneration.

(viii) Larval forms like parenchymula and amphiblastula are present in the life-cycle.

Now the situation as regards the systematic position is concerned is as follows. Sponges are on a side branch of the direct line of evolution. Although they have some superficial resemblances with metazoa but show no embryological or genetic resemblances. Therefore zoologists have separated them from metazoa and have placed them in a separate sub-kingdom. They have divided the entire animal kingdom into three sub-kingdoms—**protozoa, parazoa** and **metazoa** (or Eumetazoa). The sub-kingdom parazoa includes the sponges. Again according to **Tuzet's** view sponges evolved from protozoa and have been placed between protozoa and cnidaria in a separate phylum Porifera.

2.36. Fossil Sponges

Sponges can be found from Cambrian to recent times. It was very difficult to form a fossil sponge due to dissolving or disarticulation character of spicules. This has rendered difficult the comparison of fossil and recent sponges. However fossils of some demospongiae, Hexactinellida and Calcarea can be recognised. Lithistida, a demospongia flourished during Silurian and calcarea ranged from

Cambrian to recent and Hexactinellida were found in abundance in Devonian.

2.37. Origin of Porifera

'Which group of animals gave rise to sponges ?' It is a difficult question to answer. There are several hypothesis to show the origin of sponges.

1. An **ancient view** is that sponges originated from sluggish gastrula like ancestors. But this primitive view is not accepted at all.

2. The **second view** is that sponges originated from choanoflagellate protozoa. This theory suggested the possible origin from colonial protozoa of genus *Proterospongia*. It was considered in the line of evolution from protozoa onwards to sponges. It resembles sponges in having

(i) morphologically distinct cells,
(ii) presence of typical collared flagellated cells or choanocytes,
(iii) presence of amoeboid cells in jelly-like forming germ cells.

But there are certain objections to this view. These are

(i) the characteristic choanocytes are internal in sponges whereas these are found externally in *Proterospongia*,

(ii) evolution of canal system or presence of any sign of it in *Proterospongia*.

But the above objection can be ruled out due to the fact that (i) migration of choanocytes internally in Porifera took place at a later stage of the larva, (ii) the absence of any alimentary canal gave rise to the evolution of elaborate water canal system and (iii) development of spicules took place during their further evolution.

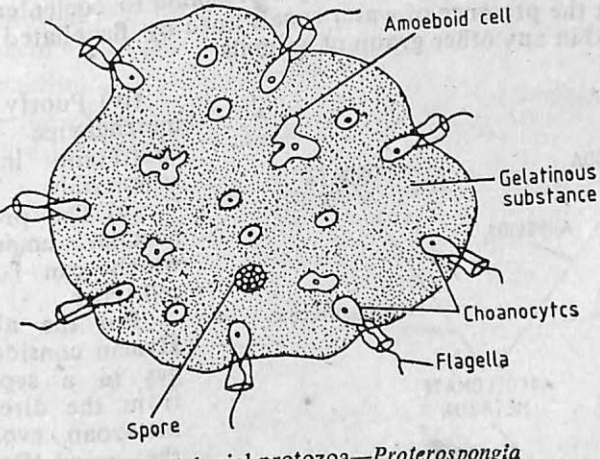


Fig. 2.35. Colonial protozoa—*Proterospongia*

3. In the sponge larva choanocytes are absent and non-collared flagellated cells are present. This gave rise to a third theory

suggesting the probable origin of sponges from flagellated protozoa (but not choanoflagellata). This formed colony and gave rise to early sponges.

Modern workers are of the opinion that sponges are lower metazoa but they **do not stand** in the direct line of metazoan evolution. The following characters support this view :

(i) Absence of cellular layers in sponges.

(ii) Absence of division of labour as is found in metazoa.

(iii) Absence of organisation like tissue systems (connective or nervous) and organ systems (alimentary system, reproductive system etc.).

(iv) There is no distinct division of somatic and germinal part of the body to carry on distinct physiological functions.

(v) During development in metazoa, a gastrula stage arises when the future germ layers are established which later on differentiate into definite tissues or systems. These are never **reversed** during later stage of development but in sponges reversal of germ layers take place.

The above facts are enough to separate them from direct line of metazoan evolution. But at the same time there are some distinctive features in sponges which should be taken into account. These important characteristics are :

(i) In sponges although there is no tissue or organ system each cell is independent.

(ii) The large terminal opening **osculum** can be compared with **mouth** but they are not homologous on the contrary are analogous because their origin during development is from different sources.

(iii) Although spongocoel may correspond to coelenteron of cnidaria but the presence of water canals lined by flagellated cells are not found in any other group of animals.

(iv) Poorly developed mesenchyme which is contractile in osculum region only.

(v) The presence of peculiar **amoeboid cells** which can form other cell types.

For the above facts **Hyman** considered sponges in a separate line from the direct line of metazoan evolution and the word **'Parazoa'** was given for the inclusion of sponges. Parazoa is a separate division of subkingdom metazoa.

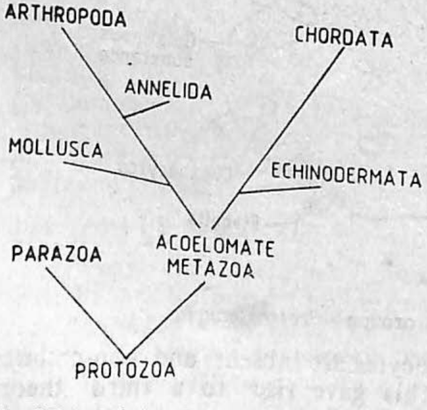


Fig. 2.36. Origin of sponges (Hyman's view)

4. Tuzet's Theory—Tuzet (1963) forwarded his theory after a long and detailed study of sponges. He was of the opinion that sponges originated from Protozoa and gave rise to Acoelomate Metazoa. This theory was based on the following facts :

(i) The characteristic choanocytes of sponges are not only restricted to this group of animals but are found in some echinoderms and in the inner lining of cnidarians (coelenterates).

(ii) Gametogenesis i.e. gamete formation in sponges is like other metazoans.

(iii) There is chemical resemblance between spongin of sponges and collagen of metazoans.

(iv) The developmental processes in *Oscarella*—a demospongia resembles the development in metazoa.

(v) It is a fact that the power of regeneration decreased from lower to higher animals. The sponges have higher regeneration power than in animals of higher grade of organization.

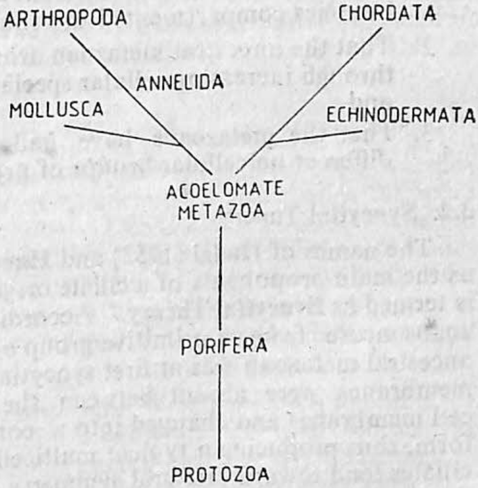


Fig. 2.37. Origin of Porifera : Tuzet's view

From the above facts it was suggested that the sponges occupy a middle position between **protozoa** and **cnidarians.**

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3. ORIGIN OF METAZOA

3.1. Origin of Metazoa

All zoologists hold the view that metazoan evolved from unicellular organisms, but opinions differ as to the particular group of unicellular forms involved in the phylogeny of metazoan and there is also disagreement about the mode of origin. The current theories on the subject can be grouped as follows :

1. That the metazoans arose from a multinucleated ciliate which becomes compartmented or cellularized;
2. That the ancestral metazoan arose from a colonial flagellate through increasing cellular specialization and interdependence; and
3. That the metazoans have had a polyphyletic origin from different unicellular groups of protozoans.

3.2. Syncytial Theory

The names of **Hadzi** (1953) and **Hanson** (1977) can be mentioned as the main proponents of a ciliate origin for metazoans. This theory is termed as **Syncytial Theory**. According to this theory the metazoans arose from a primitive group of multinucleate ciliates. The ancestral metazoan was at first syncytial in structure i.e., the cell membranes were absent between the nuclei; but later on acquired cell membranes and changed into a compartmented or cellularized form, thus producing a typical multicellular structure. Because many ciliates tend toward bilateral symmetry, proponents of the syncytial theory hold the view that (1) the ancestral metazoa was bilaterally symmetrical and (2) gave rise to the acoel flatworms, which are hence regarded as the most primitive living metazoans. The evidence to support the primitive position of acoel flatworms comes from the following facts :

1. the acoeles are in the same size range as the ciliates,
2. are bilaterally symmetrical, and
3. tend toward a syncytial condition.

Further, the ciliate macronucleus, which is absent in acoels, is supposed to have been absent in the **multinucleate prociliate stock** from which the metazoans arose. The macronucleus is assumed to have developed later in the evolutionary line leading to higher ciliates.

3.3. Objections to Syncytial Theory

However, there are a number of objections to the Syncytial theory.

1. The opponents of this theory rightly opine that nothing comparable to cellularization occurs in the ontogeny of any of these groups*. As a matter of fact, the syncytial nature of acoel tissue, arises secondarily after typical, cytosomal, embryonic divisions.

2. Moreover, a ciliate ancestry fails to explain the general occurrence of flagellated sperm in metazoans. No such cells are produced in ciliates, and this fact makes it necessary to assume that in metazoan ancestor the motile sperm arose **de-novo.**

3. The most serious and damaging objection levelled against the Syncytial theory is that if we accept this theory we must also necessarily accept that the acoels are the most primitive living metazoans. Bilateral symmetry then becomes the primitive symmetry for metazoans; this means that the radially symmetrical cnidarians must be derived secondarily from the flatworm—this is not acceptable to zoologists.

3.4. The Colonial Theory

According to this theory the metazoans are derived from a colonial flagellate. This theory is the classic and the most accepted theory of the origin of metazoans. This idea was first conceived by **Haeckel** (1874), later modified by **Metschnikoff** (1887) and about 44 years after was revived by **Hyman** (1940). This theory holds that the flagellates are the ancestors of the metazoans. In support of the flagellate ancestry of the metazoans the following facts are put forward as evidence :

1. Flagellated sperm cells are found throughout the metazoa.
2. Flagellated body cells are of common occurrence among the lower metazoans, especially among Porifera and Cnidaria.
3. True sperm and eggs have evolved in the phytoflagellates.
4. The phytoflagellates show a tendency towards a type of colonial organization that could have led to a multicellular organization, the first step in this must have been the establishment of a differentiation between somatic and reproductive cells; in fact such a differentiation is found in **Volvox.**

The Colonial theory holds that the ancestral metazoan probably arose from a spherical, hollow, colonial flagellate. In this spherical hollow colonial flagellate, the cells on the outer surface were flagellated like Volvox, and the colony had a distinct anterior-posterior axis and used to swim freely with the anterior pole directed forward, and there had appeared a differentiation of somatic and reproductive cells. This stage was termed as the **blastea** in Haeckels original theory, and the hollow blastula or coeloblastula was regarded to be a recapitulation of this stage in the embryonic development of living

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[*] Cellularization takes place in the superficial cleavage of arthropod eggs, but this is not a primitive rather a very specialized condition associated with abundant yolk material in these eggs.

metazoans. Haeckel opined that the blastea invaginated to give rise to a double-walled, sac-like organism, the **gastraea**. This was the hypothetical metazoan ancestor, equivalent to the gastrula stage which is formed in the embryonic development of living metazoans. In addition to the above said embryological evidence, Haeckel also noted the close similarity in structure between gastrae and some lower metazoans such as sponges and hydrozoan cnidarians both of which are double-walled with a single opening, the mouth (paragastric cavity in sponges and gastro-vascular cavity in hydrozoan cnidarians—rather in all coelenterates).

Metschnikoff later on modified the Haeckel's gastraea. Metschnikoff noted that the primitive mode of gastrulation in cnidarians is by **ingression**, in which the cells are proliferated from the blastula wall into the interior blastocoel so that the blastula is changed with a solid gastrula—**stereogastrula**. The inner mass of cells represents endoderm and outer layer represents the ectoderm. According to Metschnikoff, contrary to the contention of Haeckel about gastrula formation by invagination, the invagination is apparently a secondary embryonic short cut, the primitive mode of gastrulation is by ingression. Contrary to the contention of Haeckel, Metschnikoff therefore argued that the gastraea was a solid rather than a hollow organism in the ancestry of metazoans.

In accordance with Metschnikoff's revision, the followers and elaborators in recent years have picked up the evolution of Metazoans from Haeckel's blastae; through inward proliferation of cells from blastaea wall and their migration into the interior the originally hollow sphere changed into an organism having a solid structure (Fig. 3.1.) It is held that the body of this hypothetical ancestral

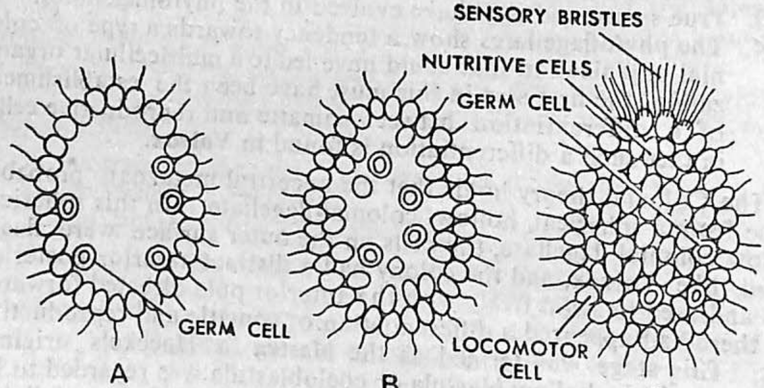

Fig. 3.1. A. Hypothetical ancestral blastae, B. Multipolar ingression, C. Hypothetical planuloid ancestor

metazoans was ovoid and radially symmetrical. The outer layer of cells was flagellated and performed a locomotor sensory function. The solid mass of interior cells assumed the functions of nutrition and reproduction. Since this hypothetical ancestral metazoan lacked a mouth so food could be engulfed anywhere on the outer surface and passed to the interior. As this hypothetical organism closely resembles the **planula** larva of cnidarians, it has been called the **planuloid** ancestor. The lower metazoans are believed to have arisen from such a free-swimming, radially symmetrical planuloid ancestor. On the basis of this theory, the primary radial symmetry of the cnidarians can be said to be derived directly from the planuloid ancestor. The bilateral symmetry of the acoelomate flatworms would hence represent a later modification in symmetry.

Among the existing flagellates the fresh-water volv-coid phytoflagellates best fulfil the qualifications for metazoan ancestors. These plant-like organisms have cellulose walls, chlorophyll, and autotrophic nutrition and go through reduction divisions following fertilization. If the phytoflagellates are the proginators of Metazoa, as has been advocated by some biologists, then it becomes essential to postulate that at sometime in the course of above described evolutionary event these plant-like characters were lost for ever.

A more likely hypothesis is that some groups of zooflagellates which are now extinct, gave rise to metazoans. These zooflagellates possessed similar colonial organization as found in the volvoci-phytoflagellates.

Most of the zoologists hold the view that flat-worms are probably the most primitive of the bilateral animals. Contemporary supporters of the Colonial Theory suppose that certain of the ancestral planuloid stock might have started a life on ocean bottom and consequently developed a creeping mode of locomotion over rocks and other objects. This could have caused a differentiation between dorsal and ventral surfaces and might have also led to the development of a ventrally situated mouth. Such differentiation would have produced a bilateral symmetry and would have led to the formation of a primitive flatworm.

Placozoa

Trichoplax adharens is a minute animal-like, multicellular organism (Fig. 3.2) discovered in a European sea-water aquarium in 1883 and has since been cultured and studied many times. Its body is flat, the lower surface is concave and upper flat. The body is composed of two outer layers of flagellated epitheloid cells, which lodge between them an inner layer of loose, contractile, stellate cells-like mesenchyma. The margin of the body is irregular. The animal changes shape like an amoeba. It creeps over the substratum by means of its flagella and feeds upon minute organic particles. The organic particles are engulfed by the cells of the lower epithelium. The organism undergoes asexual reproduction by fission and by budding. However, eggs arising form the ventral epithelium have been also observed within the internal mesenchyme-like layer. The DNA content is smaller than that found in any other animal.

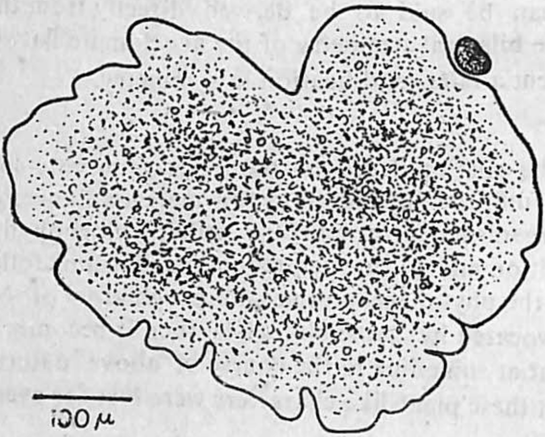

Fig. 3.2. Dorsal view of *Trichoplax adherens*. The organism is greatly flattened. Note the irregular outline and amoeboid shape.

In the beginning the zoologist regarded that **Trichoplax** was a larval stage of some unidentified animal. However, now it has become established without any doubt that it is indeed an adult organism and not a larva. *Trichoplax* may represent the most primitive living metazoan because it possesses a number of features speculated for the placuloid ancestor described above and it is for this reason that after dealing with various views on Metazoan origin in the above paragraphs the account of *Trichoplax* has been given here at the end.

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4. PHYLUM : COELENTERATA (Cnidaria)

4.1. Coelenterata (Cnidaria)

Coelenterata was formerly regarded as a phylum divided into a subphylum Cnidaria including **Hydra, Obelia, Aurelia,** Sea-anemones, Corals, and another subphylum Acnidaria including Ctenophora represented by *Hormiphora*, *Plurobrachia*, *Bero* etc. But in recent years **Hyman** (1940), **Barnes** (1980) and others regard the Coelenterata (Cnidaria) and Acnidaria (that is Ctenophora) as two distinct phyla because in spite of the similarities in their general grade of organization they have many dissimilarities. Here also they are treated as two distinct phyla. The coelenterates (Cnidarians) are characterized by muscular movements, nematocysts, and are either polyp or medusa type. However, the Ctenophores (Acnidarians) retain the ciliarly mode of locomotion of planula, are without nematocysts and cannot be assigned either to polyp or medusa type.

4.2. General Characters of Phylum Coelenterata (Cnidaria)

(i) They are simplest Metazoa having one continous space (Coelenteron) representing both the enteric or digestive cavity and the general body cavity.

(ii) The coelenteron opens to the outside by the mouth aperture which is surrounded by tentacles to aid in capture and ingestion of food.

(iii) The digestion is partly intracellular.

(iv) The animals are of low type of organization and possess a conspicuous radial symmetry.

(v) The body-wall is composed of two layers of cells (diploblastic), the outer ectoderm which forms the epidermis and the inner endoderm which forms the gastrodermis and in between the two layers is a gelatinous mesoglea secreted by them.

(vi) The nervous system is composed of a network of cells.

(vii) These animals have usually the power of budding by either free individuals or colonial zooids may be formed.

(viii) In sexual reproduction there occurs a uniformly ciliated larva, **planula**.

(ix) The tentacles bear nematocysts.

(x) They are either of polyp or medula type.

(xi) They are characterized by muscular movements.

(xii) Some coelenterates such as *Obelia* have both polyp and medusa stages which are regarded as different types of zooids. They perform different functions and hence we find polymorphism in these coelenterates.

(xiii) Some coelenterates such as *Obelia* and *Aurelia* possess polyp and medusa stages in their life-cycle, one giving rise to the other (polyp gives rise to medusa asexually and medusae do sexual reproduction and give rise to polyp). So there seems to occur alternation of generation in their life-cycle.

4.3. Classification of Phylum Coelenterata (Cnidaria)

Class 1. Hydrozoa—Hydrozoans may be the most primitive of the three classes of Cnidarians.

(i) Members of this class are medusoid of polypoid or show both forms in their life-cycle.
(ii) Mesoglea is acellular.
(iii) Nematocysts occur only in the epidermis.
(iv) Gametes develop in the epidermis.
(v) Hydromedusae are usually small and planktonic.
(vi) The asexual polypoid form arises from sexual medusoid form and the latter arises from the former, thus exhibiting alternation of generations in the life-cycle of some hydrozoa e.g., *Obelia*.
(vii) Associated with colonial organization hasve been the evolution of a skeleton (support) and division of labour (Polymorphism).
(viii) Naked solitary species e.g., hydras probably stem from early polypoid forms which were not colonial.
(ix) In colonial forms the asexual colonial polypoid stage is sedentary having feeding zooids, asexually reproducing zooids etc., while the saucer-shaped medusae are reproductive zooids. They are free-swimming having a velum, sense organs, well-developed musculature, thick mesoglea and net-like nervous system. The medusa bears gonads on 4 radial canals. Sexes are separate i.e., male and female medusae occur.
(x) Zygote undergoes complete cleavage and a hollow blastula is formed which changes into a solid stereogastrula whose ectodermal cells acquire cilia and then this stereogastrula changes into free-swimming planula. Planula settles down, attaches by its anterior end to a substratum and by budding forms the branched colonial polypoid stage.

The class Hydrozoa is divided into five orders :

Order 1. Trachylina—Medusoid hydrozoans lacking a polypoid stage. Medusa develops directly into an actinula. This order includes most primitive members of the class. Ex. *Liriope, Aqlaura.*

Order 2. Hydroida—Hydrozoans with a well-developed polypoid generation. Medusoid stage present or in some cases absent.

Sub-Order 1. Anthomedusae. (Athecate). Ex.—*Tubularia, Pennaria, Eudendrium, Branchiocerianthus,* the fresh-water hydras.

Sub-order 2. Leptomedusa—Hydranth surrounded by skeleton (thecate) Polymorphic. **Ex.**—*Obelia, Companularia, Sertularia, Plumularia.*

Sub-order 3. Chondrophora—Pelagic, polymorphic, polypoid colonies. Ex.—*Velella, Portia.*

Order 3. Actinulida—Small solitary forms resembling an actinula larva. Medusoid stage lacking. **Ex.**—*Halamohydra.*

Order 4. Siphonophora—Pelagic hydrozoan colonies of polypoid and medusoid zooids (=individuals). Colonies have floats or large swimming bells. Found mostly in warm seas. **Ex.**—*Physalia* **(Portugese man-of-war).**

Order 5. Hydrocorallina—Colonial polypoid hydrozoans which secrete a calcium carbonate skeleton.

Sub-order 1. Milleporina—Stinging coral. Skeleton covered by a thin epidermal layer only. Defensive polyps arise from separate pores encircling a central gastrozooid. **Ex.**—*Millepora.*

Sub-order 2. Styalsterina—A thick layer of tissues overlying the skeleton is present. Defensive and feeding polyps dwell within a common pit. **Ex.**—*Stylaster, Allopora.*

Class 2. Scyphozoa—It has the following characters :

(i) The scyphozoans are the medusoid coelenterata, pelagic and are usually called as jelly-fish. In this class medusa is conspicuous and dominant in the life-cycle; while the polypoid form is restricted to a small larval stage planula giving rise to hydratuba which changes into scyphistoma. The scyphozoans evolved early from the ancestral hydrozoans.

(ii) Due to specialization the structure of medusa has become complex e.g., larger size than most of the hydromedusae, more highly developed manubrium, cellular mesoglea gut with gastric filaments, gastrodermal nematocysts, and development of certain sense organs (tentaculocysts).

(iii) The gonads of medusa are gastrodermal, eggs are shed through mouth, zygote develops into a planula larva—hydratuba—scyphistoma—strobilation—ophyra—medusa (Aurelia). The polyp (scyphistoma) does asexual reproduction while medusa reproduces sexually. Thus in some forms e.g., *Aurelia* there is a kind of alternation of generations between medusoid and polypoid generations.

(iv) Scyphozoid medusa has the same general structure and arrangement of germ layers as the medusoid Hydrozoa but differs from them in having endodermal gastric tentacles.

(v) A true velum is absent.

The class Scyphozoa is divided into five orders.

Order 1. Lucernaridae (Stauromedusa)—Scyphozoa having conical or vase-shaped umbrella, mostly attached to foreign objects by an ex-umbrellur peduncle, tentaculocysts absent. **Ex.**—*Lucernaria.*

Order 2. Coronata—Umbrella divided by a horizontal **Coronary groove. Ex.**—*Pericopla, Nausithoe.*

Order 3. Cubomedusae—Four-sided cup-shaped umbrella, four per-radial tentaculocysts. **Ex.**—*Charybdaea.*

Order 4. Discomedusa (Semaeostomeae)—Flattened saucer or disc-shaped umbrella, not fewer than eight tentaculocysts—4 per. and 4 inter-radial; the square mouth produced into 4 long oral arms. **Ex.**—*Aurelia.*

Order 5. Rhizostomeae—Mouth obliterated by the growth across it of the oral arms; the stomach is continued into canals which open by funnel-shaped apertures on the edges of the arms. **Ex.**—*Pilema.*

Class 3. Anthozoa or Actinozoa—The following are their characteristics:

(i) Exist only in the polyp form, no medusa stage.

(ii) Differ from hydrozoan and scyphozoan polyp in possessing a stomodaeum, paired mesenteries (their free ends bear coiled mesenteric filaments like the gastric filaments of scyphozoa but are partially ectodermal in origin).

(iii) Body.wall consists of ectoderm and endoderm separated by a strong mesoglea having fibres and cells.

(iv) Stomodaeum consists of the same layers reversed i.e., its lining membrane is ectodermal. The mesenteries are formed by a double layer of endoderm with a supporting plate of mesoglea.

(v) More complex nematocysts than in Hydrozoa and Scyphozoa are found in the tentacles, body-wall, stomodaeum and mesenteric filaments.

(vi) Muscular system is well-developed containing both ectodermal and endodermal fibres and endodermal muscule processes.

(vii) Nervous system is a typical nerve net.

(viii) Gonads develop in the mesenteries, sex cells are located in the endoderm, and sperm and ova are discharged into the coelenteron.

(ix) The zygote develops into a planula which after swimming freely for some time settles down and metamorphoses into the adult form.

(x) Except in one doubtful instance there is no alternation of generations.

Sub-Class 1. Hexacorallia

(i) Tentacles and mesenteries very numerous, arranged in multiples of five or six.

(ii) Tentacles are simple, unbranched, hollow cones.

(iii) Two siphonoglyphs are present and two pairs of directive mesenteries; the remaining mesenteries are generally arranged in couples with the longitudinal muscles of each couple facing one another.

Order 1. Actiniaria—(a) Simple Hexacorallians but some form small colonies. (b) Tentacles and mesenteries are numerous. (c) There is no skeleton. (d) One or two grooves (siphonoglyphs) in the gullet.

This order includes the Sea-anemones—*Metridium, Urticinia, Edwardsia, Minyas, Adamsia.*

Order 2. Madreporaria—(a) They resemble the Actiniaria in the general structure of soft parts. (b) Usually form colonies. (c) Always have an ectodermal calcareous skeleton.

This order includes many stony Corals—*Corallium rubrum, Astraea pallida, Dendrophyllia nigrescans, Madrepora aspera.*

Order 3. Zoantheria—(a) Solitary or colonial Hexacorallia with one ventral siphonoglyph. (b) Tentacles are unbranched. (c) Body-wall encrusted with foreign calcareous bodies. (d) Some have a horny axial skeleton.

Ex.—*Zoanthus sociatus.*

Order 4. Antipatheria—(a) Compound tree-like Hexacorallia in which the tentacles and mesenteries are relatively few (6 to 24) in number. (b) A skeleton is present in the form of a branched axis made up of chitin, developed from the ectoderm, which extends throughout the colony. Ex.—Black Coral, *Antipathes termatensis.*

Sub-class 2. Octocorallia

1. Tentacles and mesenteries always eight in number.
2. The tentacles pinnate; i.e., produced into symmetrical branchlets.
3. Never more than one siphonoglyph, which is ventral in position, i.e., faces the proximal end of the colony.
4. The arrangement of mesenteries is not always in couples (or pairs) and all their longitudinal muscles are directed ventrally i.e., towards the same side as the siphonoglyph.

Order 1. Alcyonaria—(a) Octocorallaria in which the skeleton more or less always consists of calcareous spicules or irregular bodies containing mesoglea but originating from wandering ectoderm cells. The 'Deadman's fingers' *Alcyonium* has skeleton of this type. (b) In other cases the spicules may be aggregated to coherent skeleton which may form a branched axis to the entire colony, e.g., valuable

Red Coral—*Corallium rubrum*; or a series of connected tubes for the individual polyps as in Organ pipe coral *Tubipora musica*, (c) In some (viz. 'Blue Coral' *Heliopora*) the skeleton may be massive and resemble that of Madreporaria, (d) Most genera are compound, a few are simple e.g., *Hartea*, the latter ones are regarded as a larval form.

Order 2. Gorgonaria—(a) Compound tree-like Octocorralia, (b) Skeleton calcareous or horny, ectodermal in origin forming a branched axis throughout the colony. (c) Spicules are found in the mesoglea, (d) Siphonoglyph absent.

Ex.—"Sea-fans" *Gorgonia verrucosa.*

Order 3. Pennatularia—(a) Colony usually elongated, its one end is embedded in the mud at sea-bottom, while the opposite distal end bears the polyps, usually on lateral branches, (b) Stem is supported by a calcareous or horny skeleton. (c) Polyps are dimorphic.

Ex.—"Sea-pens",*Pennatula sulcata.*

CLASS—HYDROZOA

OBELIA

4.4. Classification

Phylum—Coelenterata
Sub-phylum—Cnidaria
Class—Hydrozoa
Order—Hydroidea
Sub-order—Leptomedusa
Genus—*Obelia*

Obelia is a whitish or brownish common plant-like colonial Hydroid Coelenterate (Fig. 4.1). In the shallow sea-water it is found attached to the rocks and surface of sea-weeds.

Obelia colony consists of many branches. The branches are of two types—the vertical branch is called **hydrocaulus** and the horizontal branch is called the **hydrorhiza** which is attached to the substratum. Hydrocaulus and hydrorhiza consist of two distinct layers : (a) Perisarc and (b) Coenosarc. The cuticullar perisarc is transparent yellow in colour, tough chitinous outer non-cellular layer secreted by ectoderm. It is the protective outer layer. The Coenosarc is hollow and its continuous cavity is continued into the cavities of Polyps thus containing a grastrovascular cavity containing a fluid. Coenosarc has an outer layer of ectoderm and an inner layer of endoderm. From the hydrocaulus, several side branches arise which are ringed and their apex is expanded into hydra-like polyps or the **hydranths.** Hydranths are the feeding zooids. In the axil of the hydranths are found **blastostyles**, they are reproductive zooids. They give rise to small lateral offshoots, the medusa buds which develop into disc-like **medusae** and remain attached with the blastostyle for sometime by rod-like structure. The **medusae** are reproductive zooids. They do sexual reproduction.

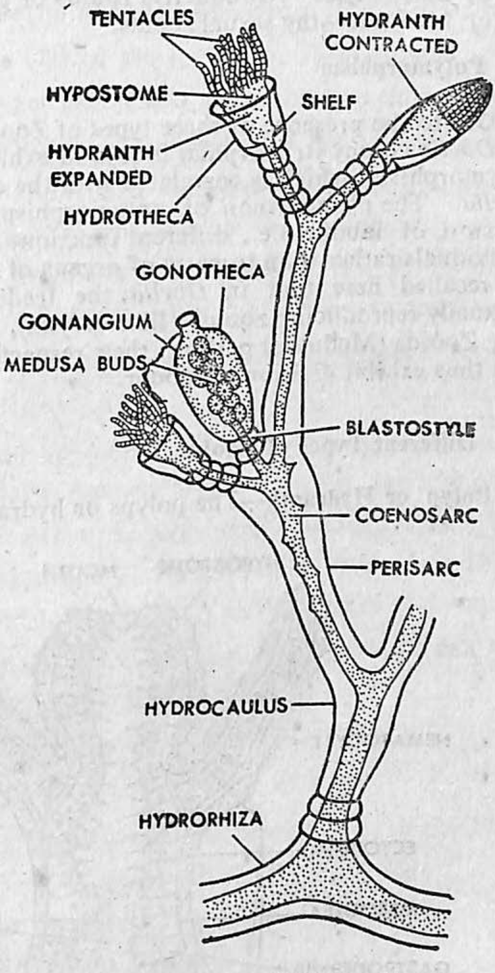


Fig. 4.1. A part of *Obelia* colony

Thus *Obelia* colony is trimorphic, having
(a) Polyps or hydranths—feeding zooids,
(b) Blastostyles—reproductive zooids or gonangia,
(c) Medusae—the sexual zooids.

4.5. Polymorphism

Due to the presence of three types of Zooids or the individuals the *Obelia* colony (trimorphic) is said to exhibit the phenomenon of polymorphism which is correlated with the colonial organization of *Obelia.* The phenomenon of polymorphism is essentially one of division of labour i.e., different functions are assigned to different individuals rather than to parts of organs of one individual. It may be recalled here that in *Obelia* the feeding Zooids (Hydranths), asexually reproducing zooids (Blastostyles), and sexually reproducing Zooids (Medusae) perform their respective functions for *Obelia* and thus exhibit division of labour.

4.6. Different Types of Zooids

Polyp or Hydranth—The polyps or hydranths are feeding zooids

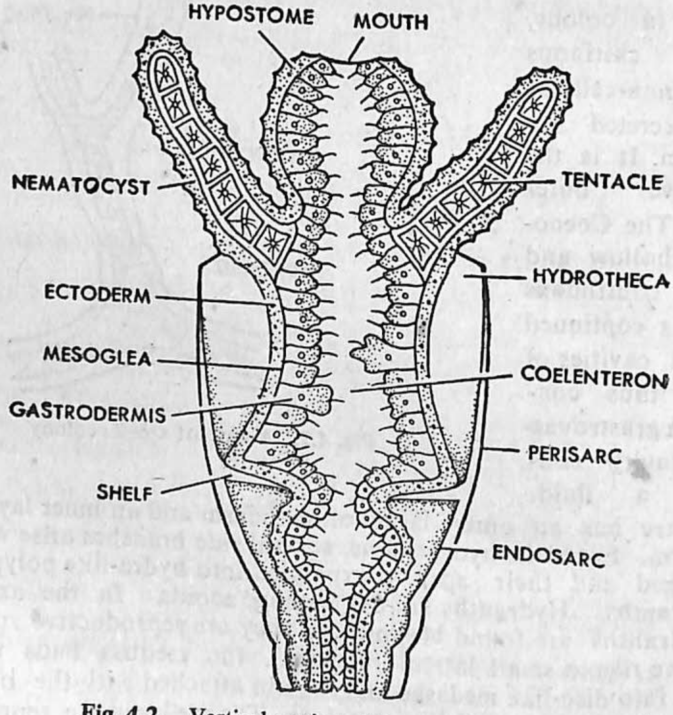


Fig. 4.2. Vertical section of hydranth of *Obelia*

They are numerous. They are found attached at the apical or free (or distal) ends of the hydrocauli and their branches. The tubular perisarc is ring-shaped at the base of the hydradth. The tubular perisarc expands into a wine glass shape or conical cup called **hydrotheca** (Fig. 4.2). The hydrotheca protects the polyps or hydranths which are cylindrical conical and vase-like hollow sac somewhat yellow in colour and opening at one end to the outside by mouth which is situated at the tip of a conical hypostome and at the other end towards its base its coelenteron opens into the coenosarcal canal of the hydrocaulus. The base of the polyp rests on the shelf formed by the hydrotheca.

Around the base of the hypostome are 24 solid **tentacles** arranged in a circle. Each tentacle has an outer ectoderm and an inner endoderm. There are numerous nematocysts on the tentacles. The whole polyp can contract and is withdrawn into the hydrotheca. The mouth can dilate and contract as required and thus changes the shape of hypostome from conical to trumpet-like. Tentacles can also rapidly contract and curve over the hypostome.

4.7. Histology

As seen under light microscope in longitudinal section the body-wall of the hydranth is seen to consist of two layers of cells :

(a) the outer **ectoderm** or **epidermis.**

(b) the inner **endoderm** or **gastrodermis,**

and separating the two layers is a delicate membrane called **mesoglea** or supporting lamella. The hypostome also consists of these two layers of cells. The layers of polyps are continued as Coenosarcs. The other zooids are also made up of the same layers described above.

Ectoderm is thin and is made up of columnar epithelium. The cells are conical in shape. Interstitial cells may be present in the space between the narrow ends of ectodermal cells. But **Grove** and **Newell** opine that the interstitial cells are completely absent. Nematocysts are also present in the ectoderm which act as organs of offence and defence. The nematocysts are specially abundantly present in the tentacles where they constitute annular batteries.

Endodermal cells are large and glandular and their free ends have pseudopodia or flagella, the movement of the latter cause the entry of food particles into the coelenteron (enteron). Gland cells with granular protoplasm are also present in endoderm. They produce digestive enzymes. Tentacles and hypostome also have a layer of unstriated muscle fibres lying between ectoderm and mesoglea which helps in rapid contraction of tentacles. In hypostome, muscle lying transversely serves to contract the cavity and act antagonistically to the action of longitudinal muscle fibres.

4.8. Blastostyles

They are asexually reproducing zooids called as blastozooids (gonozooid called gonangium). The blastostyles are covered by the extension of perisarc called as gonotheca (Fig. 4.3). They are formed when the hydrocaulus or vertical stems have become fully grown. Blastostyles are found towards the proximal region of the obelia colony in the axils of the peduncles of the polyps and the main stem. The blastostyles are formed by gemmation. They are long cylindrical or club-shaped structures enclosed in a transparent perisarc which is called here the gonotheca. Blastostyles are modified zooids without mouth and tentacles. Its body-wall has also an outer layer of ectoderm cells and inner layer of endoderm cells, a thin mesoglea in between the two. The two-layered body-wall encloses

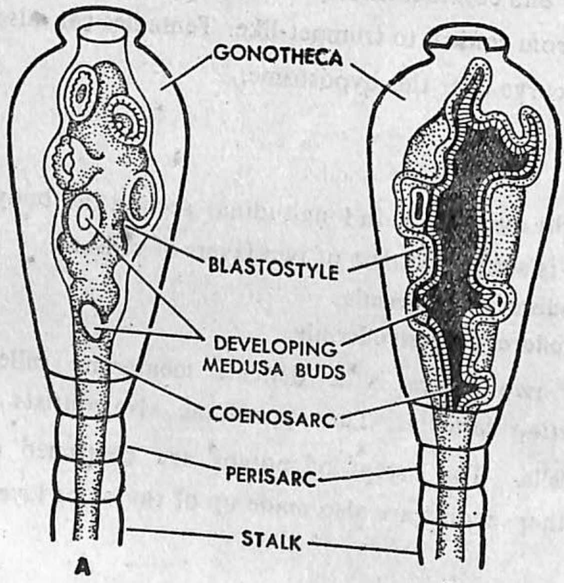


Fig. 4.3. Blastostye of *Obelia* : A. Entire; B. L. S.

a central space or gastrovascular cavity which is rudimentary and does not open to the exterior.

The blastostyles have many saucer-shaped or bell-shaped medusae arranged along a central axis in different stages of development. These are called as medusa buds which finally develop into medusae having gonads. The development of medusa buds begins as minute protuberances or buds from the wall of the blastosyle. On attaining maturity the medusae separate from the blastostyle and come out through an opening situated at the distal end of blastostyle. The blastostyle together with its medusae buds and the extension of perisarc) called as gonotheca) is called as gonangium.

4.9. Development of Medusa from Blastostyle

Medusae develop as said above, as buds on the blastostyles. In initial stage of the formation of medusa it is just like a small diverticulum or projection of the cavity of the blastostyle. This diverticulum increases in dimension at its extremity and forms a small vesicle enclosed by ectoderm, mesoglea, and endoderm. It also has enteron of blastostyle (Fig. 4.4). The medusa remains in contact with the balstostyle by a narrow stalk. Subsequently, a cavity appears below the subumbrellar surface by the separation of distal region of ectoderm into two layers : (a) an outer ectoderm and (b) an inner ectoderm. There is a cavity between these two layers of ectoderm.

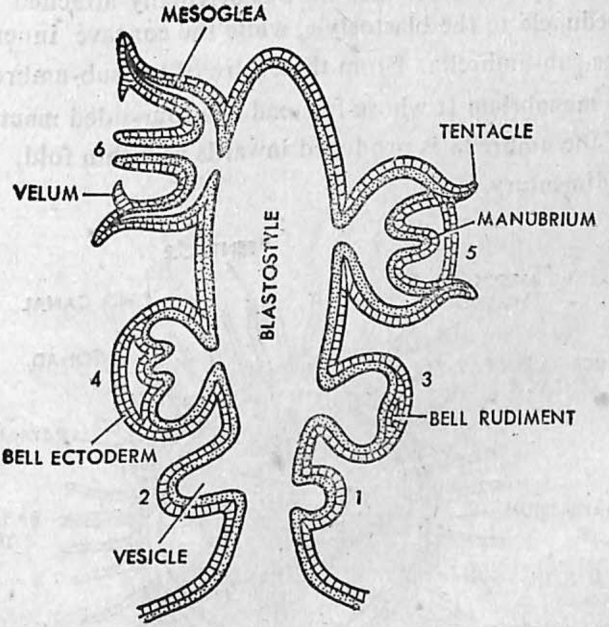


Fig. 4.4. Development of medusa from a blastostyle

This small sac is formed with a cavity and encloses two layers of ectoderm. It is called bell-rudiment. It grows in size and assumes the form of sub-umbrellar cavity with the manubrium lying in the centre. Later on the bell-ectoderm (outer ectoderm) breaks up and the remaining part of it constitutes a circular shelf, termed as Velum, projecting inwards from the margin of the umbrella. It is quite rudimentary here. When the medusa acquires its final shape, mouth breaks through the apex of the manubrium. The stalk also ruptures later on and the medusa becomes free and comes out through the opening at the distal end of gonotheca, and the medusa swims freely in sea-water.

4.10. Medusae or Sexual Zooids

Fully grown medusae (Fig. 4.5,4.6, 4.7. 4.8) are 1/4 of an inch in diameter. They are saucer-shaped or like a circular disc which is bell-like. This is called umbrella. Its convex outer surface is called exumbrella by which the medusa was originally attached through a short peduncle to the blastostyle, while the concave inner surface is called as sub-umbrella. From the centre of the sub-umbrella, hangs down a **manubrium** at whose free end is a four-sided **mouth**. The free edge of the umbrella is produced inwards as a thin fold, the **velum**. It is rudimentary.

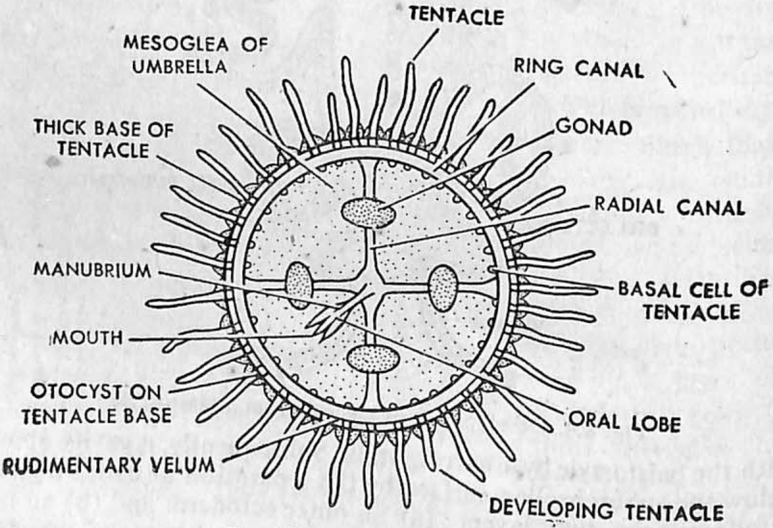


Fig. 4.5. Medusa in oral view

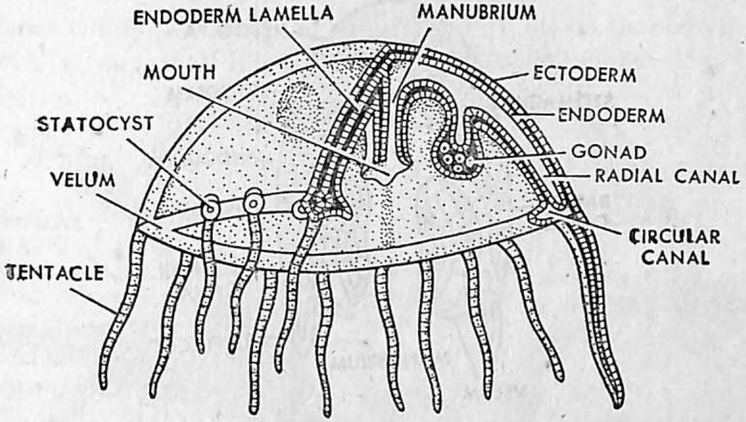


Fig. 4.6. Medusa in section

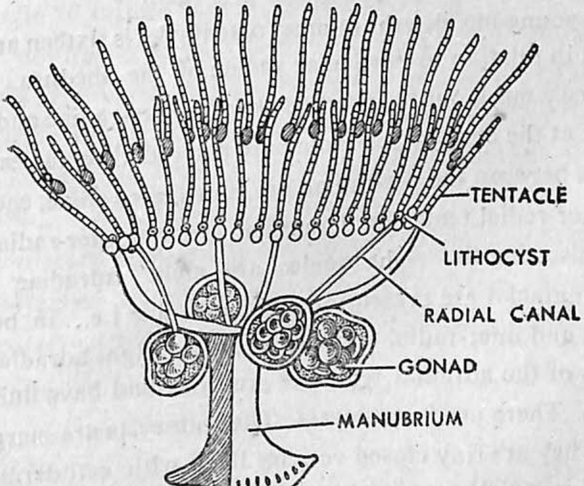


Fig. 4.7. An everted medusa

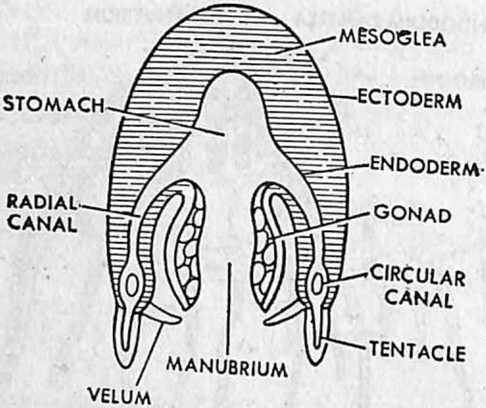


Fig. 4.8. Medusa showing its structure

The cavity of the manubrium leads into a central or enteric cavity from which arise four radial canals which open into a circular canal near the margin of the umbrella. The medusae are carnivorous-like polyps. The food is taken in the mouth and after being digested in the manubrium is supplied to the whole medusa. There are many tentacles round the margin of the medusa. These are solid, contractile and beset with nematocysts.

In the young medusa the number of tentacles is sixteen and these are described in relation to particular radiae of the medusa. The four radial canals mark out four radiae called as per-radiae and the tentacles lying at the ends of per-radiae are per-radial tentacles. Bisecting the angles between the per-radiae are four inter-radiae, each of which has an inter-radial tentacles. Thus there are four inter-radial tentacles. Radiae bisecting the eight angles are eight adradiae and eight adradial tentacles are present on eight adradiae i.e., in between the per-radial and inter-radial tentacles there are eight adradial tentacles. The bases of the adradial tentacles are thick and have fluid sacs, the statocysts. There are 8 statocysts. The statocysts are marginal sense organs. They are tiny closed vesicles lined with ectoderm and filled with fluid in which minute calcareous grains occur. Inside the statocyst there are particles of calcium sulphate, lithocysts or statoliths.

In these vesicular statocysts calcium sulphate concretions lie next to a sensory cilium. The tilting of the bell margin moves the concretion in such a way that it touches and stimulates the cilium (Fig. 4.9)

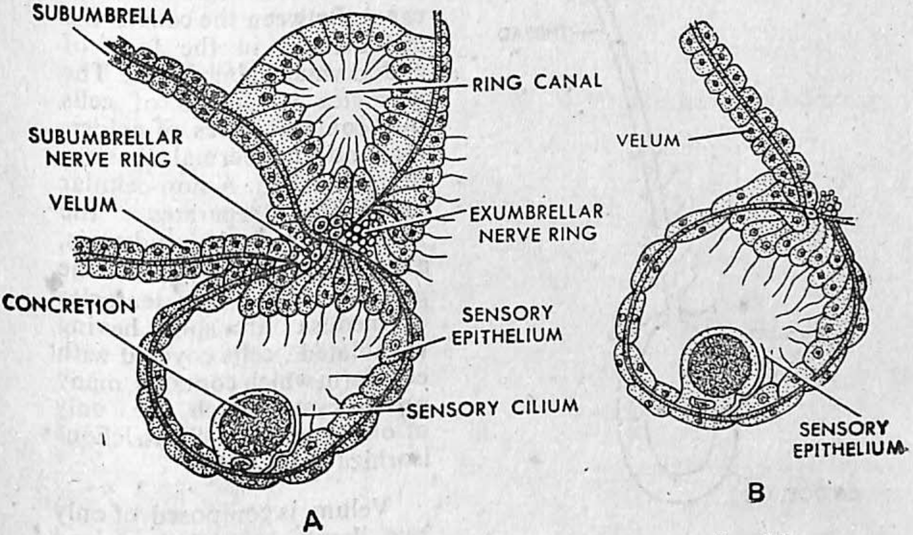


Fig. 4.9. Statocysts: A. in horizontal position; B. in tilted position

(**Single**, 1975). The statocyst stimulation inhibits muscular contractions on that side of the bell, and the opposite side throws water beneath the tilted margin to bring about righting. The medusa then responds by muscular contractions to bring itself back into a horizontal position. Thus the function of statocysts is to maintain equilibrium and co-ordination of swimming movements of medusa. The bases of all 16 tentacles appear swollen due to the accumulation of interstitial cells also.

A sexually mature medusa has 4 groups of gonads on subumbrellar surface attached to the middle of the 4 radial canals. The medusae are unisexual bearing either male gonads (testes) or female gonads (ovary).

4.11. Histology

Like Polyp the body-wall of medusa also consists of ectoderm, relatively thick mesoglea and endoderm. Ectoderm is found on both

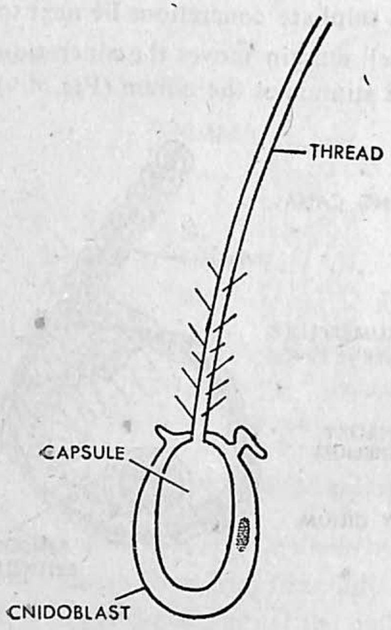


Fig. 4.10. Basitrichous isorhiza

the ex-, and sub-umbrellar surfaces while endoderm lines the enteric cavity (stomach). radial canals and circular canal. Between the canals the endoderm is in the form of endodermal lamella. The mesoglea is devoid of cells but contains fibres of epidermal and endodermal (gastrodermal) origin. A non-cellular membrane separates the mesoglea from the epidermis, and another bounds the gastrodermis. The tentacles of medusa are solid having vacuolated cells covered with ectoderm which contains many nematocysts which are only of one type viz., Basitrichous isorhiza (Fig. 4.10).

Velum is composed of only two layers of ectoderm and a separating mesoglea.

The muscular system of medusa is more specialized than that of polyp. The gastroderm cells do not possess contactile extensions and the muscular system is thus restricted to the epidermal layer. The muscular system is well-developed around the bell margin, and sub-umbrellar surface where the fibres form circular sheets, each separated by radial canals. The muscle fibres are striated. They contract to produce rhythmic contractions of the bell which drive the water out from beneath the sub-umbrella. The mesoglea with its elastic fibres act antagonistic to the force of contraction of muscle fibres to restore the bell shape between contractions.

The medusa swims actively by alternate opening and closing of the bell affected by alternate contraction and expansion of muscle fibres and mesoglea with the fibres present in it. Although medusae usually turn when swimming the general direction is vertical. A series of pulsations drive it upward but then it slowly sinks.

The nervous system of medusa is more highly specialized than that of the polyp. The epidermal nerve cells are organized and concentrated in the margin of the bell into two nerve rings, one above and the other below the attachment of the velum. Nerve rings are connected with nerve fibres innervating the tentacles, the musculature and the sense organs. The two nerve rings are also connected together by nerve fibres. The lower ring is the centre of rhythmic pulsation that is it has the pacemakers. The statocysts are connected with lower ring.

4.12. Life-History of Obelia

The *Obelia* colony reproduces (Fig. 4.11) asexually by budding

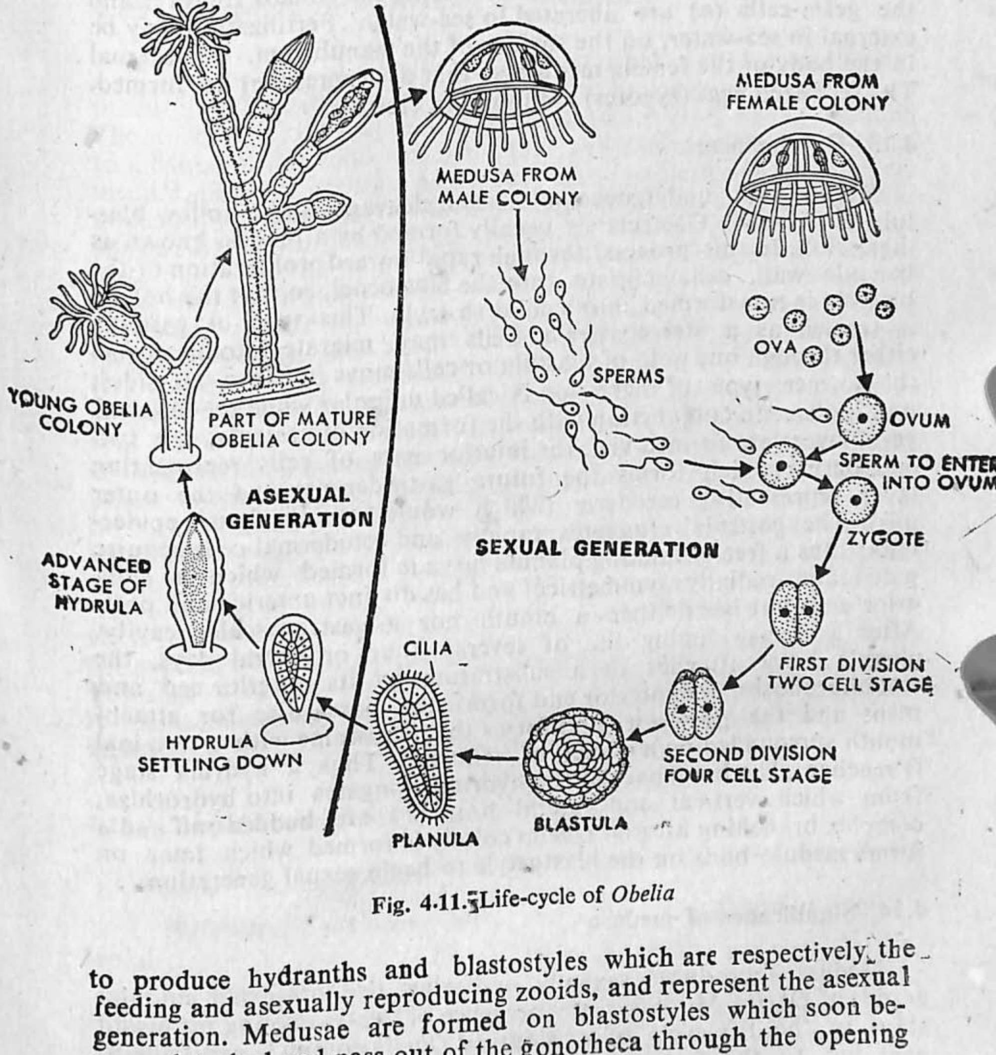


Fig. 4.11. Life-cycle of *Obelia*

to produce hydranths and blastostyles which are respectively the feeding and asexually reproducing zooids, and represent the asexual generation. Medusae are formed on blastostyles which soon become detached and pass out of the gonotheca through the opening in the distal end. The medusae are the sexually reproducing zooids and represent the sexual generation. Each medusa has 4 gonads, one on each radial canal on subumbrellar surface in the form of ovoid mass. The medusae are dioecious. Some of the medusae of *Obelia* produce eggs, and others produce spermatozoa. The gonads are formed by the epidermal or gastrodermal epithelial cells of the manubrium and then migrate along the radial canals to the specific locations in the epidermis (that is, in the gonads.) From these clusters are formed the four gonads. When sperms and ova are matured the endodermal wall surrounding the gonads ruptures and the germ-cells (n) are liberated In sea-water. Fertilization may be external in sea-water, on the surface of the manubrium, or internal in the body of the female medusa so that a zygote ($2n$) is formed. The fertilized eggs (zygotes) are found in clusters.

4.13. Development

The zygote undergoes holoblastic cleavages and a hollow blastula is formed. Gastrula is usually formed by a process known as ingression. In this process, through rapid inward proliferation of the blastula wall, cells migrate into the blastocoel, so that the hollow blastula is transformed into a solid gastrula. This type of gastrula is termed as a **stereogastrula**. Cells may migrate into blastocoel either through one pole of blastula or cells move in from all sides, the former type of ingression is called unipolar while the latter as multipolar. In conjunction with the formation of gastrula, the two germ layers are formed viz., the interior mass of cells representing endoderm (which forms the future gastrodermis) and the outer layer representing ectoderm (which would form the future epidermis). The gastrula elongates rapidly and ectodermal cells acquire cilia; thus a free-swimming planula larva is formed which is elongated and radially symmetrical and has distinct anterior and posterior ends but has neither a mouth nor a gastrovascular cavity. After a free-swimming life of several hours or several days, the planula larva attaches to a substratum by its anterior end and metamorphoses. Its anterior end forms the basal disc for attachment and the posterior end forms the hypostome with a terminal mouth surrounded by a circlet of tentacles. Thus a hydrula stage is reached. The basal part of the hydrula elongates into hydrorhiza, from which vertical and lateral branches are budded off and a complex branching asexual *Obelia* colony is formed which later on forms medusa buds on the blastostyle to begin sexual generation.

4.14. Significance of medusa

Medusa reproduces sexually and gives rise to asexual colonial zooids of *Obelia*. Moreover, the presence of free-swimming medusoid stage in the life-cycle of a sedentary *Obelia* colony is very significant due to the fact that medusa does locomotion and brings about dispersal of the species and so establishes the colonies of *Obelia* in new habitats were a different food source may be present. The overcrowding of *Obelia* colony at one locality leading to the chances of intraspecific and interspecific competition pressures are also minimized by the mobile medusae. The minimizing of overcrowding at one place and the dispersal to new habitats brought about by medusae certainly ensure the better chances of survival of *Obelia*.

4.15. Alternation of Generations or Metagenesis

The life-cycle of *Obelia* colony described above gives the impression that alternation of generations or metagenesis takes place. The sedentary colonial asexual hydroid phase gives rise by budding to medusae which represent the sexual generation. The gonads of medusa produce sperms and ova. The fertilized ovum ultimately gives rise to planula larva which gives rise to *Obelia* colony. In other words the sexual medusa gives rise to asexual colony by sexual method. This alternation of generations or metagenesis confers upon the species not only genetical advantage but also ecological advantage. When each asexual and sexual form has a large reproductive capacity, one sexual, the other asexual, the species has the less chance of being eliminated due to predation or competition. However in the strict sense the life-cycle of *Obelia* does not represent a true case of alternation of generations because in the true case of alternation of generations which occurs in the life-cycle of certain plants such as Ferns, the asexual diploid ($2n$) phase forms haploid (n) sexual phase by its single cell. But in the case of *Obelia*, both the sedentary asexual colonial polypoid generation and mobile sexual medusoid generation are diploid (only the sperm and ova produced in the gonads of medusa having brief existence are haploid). Moreover, the medusa (sexual phase) is not derived from a single cell of the asexual phase but is formed by many cells of the blastostyle by budding. Hence the life-cycle of *Obelia* though apparently seems to represent alternation of generations does not do so in **sensu strictu**.

4.16. Comparison of Polyp and Medusa

Polyps (Asexual Zooids)	**Medusa (Sexual Zooids)**
1. Habit—(a) Sedentary, colonial.	1. Habit—(a) Free-swimming,-solitary.
2. Position—(b) They are attached to vertical branches of the colony.	2. Position—(b) They are formed by budding from blastostyles and finally detach from it and become free-swimming.

Polyp	Medusa
3. Shape and structure—(c) They are like hollow conical sacs or wine glass-shaped having at distal end a conical hypostome or manubrium at the tip of which is a circular mouth.	3. Shape and structure—(c) They are disc-shaped or umbrella-like having an outer convex exumbrellar surface and an inner concave subumbrellar surface from the centre of which hangs down a manubrium at whose apex is a rectangular mouth.
(d) The hypostome bears 24 solid tentacles forming a circlet around the mouth.	(d) The margin of the adult medusa bears numerous solid tentacles but there are 16 (4 perradial, 4 interradial, 8 adradial) tentacles on the margin of young medusa.
(e) The bases of tentacles are not swollen.	(e) Swollen due to the presence of interstitial cells.
(f) Velum is lacking.	(f) A rudimentary velum is present around the margin of umbrella.
(g) Statocyst is absent.	(g) 8 statocysts situated at the bases of adradial tentacles are present. They are sensory (balancing organs).
(h) Mesoglea is like a thin layer between ecto-and endoderm.	(h) Mesoglea is thick.
(i) Endoderm does not constitute lamellae.	(i) Endoderm of oral and aboral regions forms endoderm lamellae which are formed by the fusion of endoderm of the two sides into a single layer.
(j) Coelenteron or gastrovascular cavity is wide and does not have radial and circular canal. Coelenteron is continuous with the coenosarcal cavity of the branches of the colony.	(j) The coelenteron is a short chamber represented by the space inside the stomach and is produced into 4 radial canals and a circular or marginal canal.

Polyp	Medusa
(k) Nervous system is poorly-developed, represented by scattered nerve cells and their nerve fibres in tentacles and body proper.	(k) Nervous system well-developed and includes a double ring of irregular nerve cells and their nerve fibres.
(l) Gonads are absent.	(l) 4 gonads are present, one in the middle of each of the four radial canals in the epidermis.
(m) The muscular system of polyp is poorly-developed in comparison to that of medusa, and muscles fibres are unstriped.	(m) The muscular system of medusa is more specialized than it is in Polyp. The gastrodermal cells lack muscle tails (contractile extension) and is thus restricted to epidermal layer. The muscular system is well-developed around the bell margin and subumbrellar surface forming circular sheets, each separated by radial canals. The fibres are striated and their contractions produce rhythmic pulsations of the bell which drive water out from beneath the sub-umbrella. The compressed mesogloea with its elastic fibres provides the antagonistic force to restore the bell's shape between successive contractions.
(n) Hydranths are nutritive zooids, blastostyles are asexually reproducing zooids. Both are polyps and represent asexual generation.	(n) Medusae are reproductive zooids and represent sexual generation. Their gonads produce sex cells.
(o) Reproduce asexually by the process of budding.	(o) Reproduce sexually by formation of sperms and ova. Sexes are separate.

4.17. Polyp and Medusa : Homologous

The polyp and medusa show marked differences as outlined-above while comparing the two. However, it must be remembered that both are homologous structure and they can be derived from each other. They are formed on the same fundamental plan so both the polyp and medusa are strictly homologous. Polyp and medusa show the following similarities :

1. Body-wall is diploblastic.
2. Mouth and hypostome of the polyp are homologous to mouth and manubrium of medusa.
3. The stomach, radial canals and circular canal of medusa are homologous to the gastro-vascular cavity of the polyp.
4. Both are carnivorous.
5. The convex exumbrellar surface of medusa corresponds to the base of the hydranth.
6. Both have tentacles beset with stinging cells.
7. Both polyp and medusa are radially symmetrical but the latter exhibits more complexity.

The medusa can be derived from the polyp in the following manner :

Invert the polyp with its base upwards and the hypostome bearing tentacles and mouth opening facing downwards and now suppose that its tentacular region is pulled out. Consequently polyp at first acquires a disc-like form then it assumes a saucer-like form by the further compression of basal region, with an upper convex exumbrellar surface and an inner concave sub-umbrellar surface with a long manubrium (the hypostome has changed into manubrium) hanging down from its central region. Thus a medusa-like (saucer-shaped) body is formed with a double wall to entire bell, a narrow space between the two layers having prolongation of the coelenteron which is lined by endoderm, and both exumbrellar and subumbrellar surfaces are lined externally by ectoderm. Then the continuous cavity (coelenteron) in the bell becomes obliterated by the growing together of its both inner endodermal walls so as to form the endodermal lamella and by the increase of mesogloea in the exumbrellar surface. Thus the coelenteron or central gastro-vascular cavity remains only in the 4 radial canals, and a circular canal running close to the edge of the bell. These canals constitute the gastro-vascular system of medusa (Fig. 4.12).

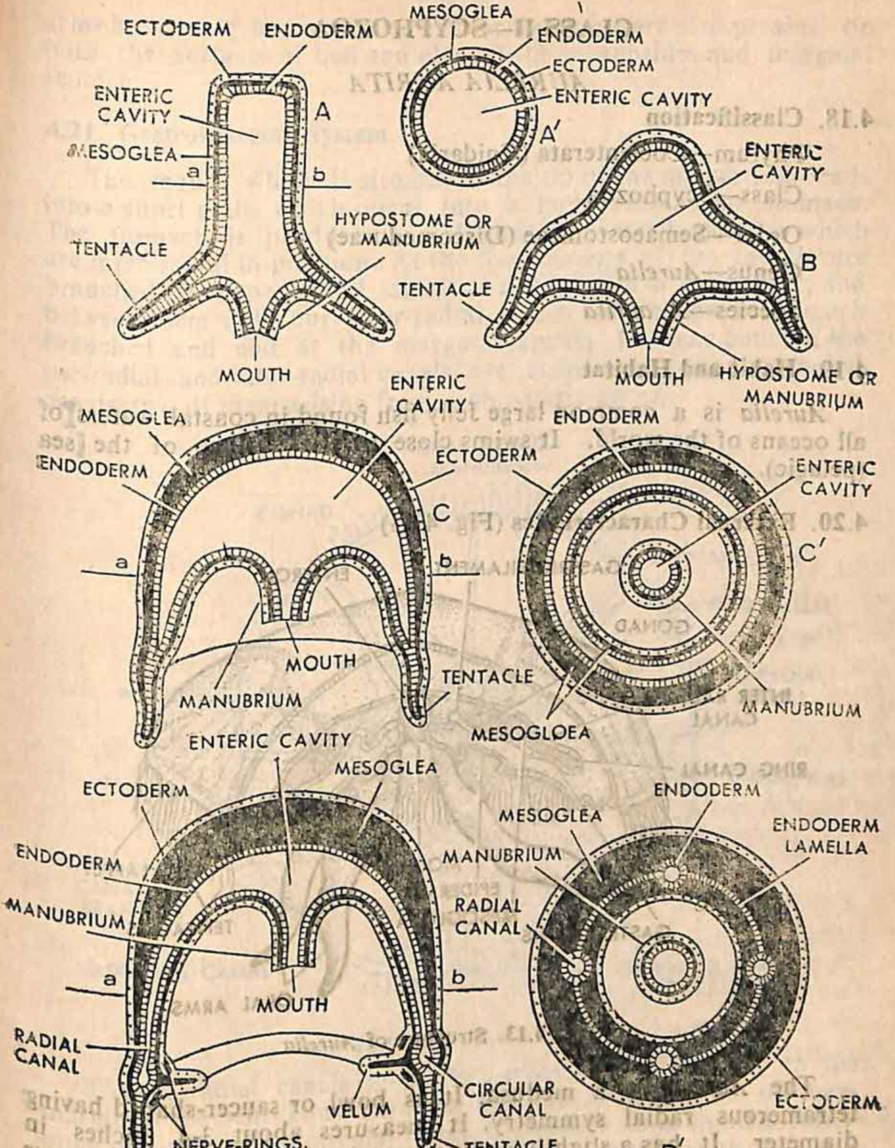


Fig. 4.12. Derivation of the medusa from the polyp: A″. longitudinal section of polyp-form along the line ab; A′ transverse section along the line ab of polyp-form; B. polyp-form with expanded tentacular region; C. vertical, and C′. transverse section along the line ab of form with extended tentacular region assuming the form of bell; D. vertical, and D′. transverse section of medusa along the line ab.

CLASS II—SCYPHOZOA

AURELIA AURITA

4.18. Classification

Phylum—Coelenterata (Cnidaria)

Class—Scyphozoa

Order—Semaeostomeae (Discomedusae)

Genus—*Aurelia*

Species—*A. aurita*

4.19. Habit and Habitat

Aurelia is a common large Jelly fish found in coastal waters of all oceans of the world. It swims close to the surface of the sea (pelagic).

4.20. External Characteristics (Fig. 4.13)

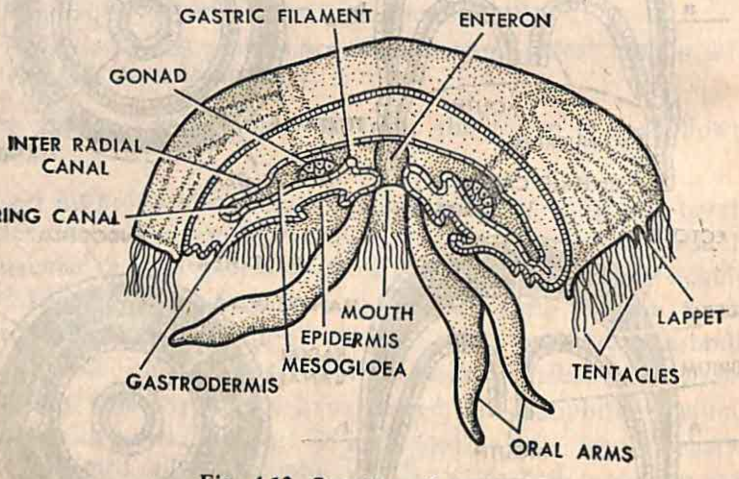


Fig. 4.13. Structure of *Aurelia*

The *Aurelia* is a medusa. It is bowl or saucer-shaped having tetramerous radial symmetry. It measures about 3-4 inches in diameter. It has a slightly convex exumbrellar and slightly concave sub-umbrellar surface. The outline is circular but the margin is broken by eight pairs of marginal lappets due to the presence of eight notches. The margin is fringed with numerous small hollow tentacles. In the centre of the sub-umbrellar surface is a short manubrium having a square mouth. The corners of the mouth have four long, tapering oral arms which are per-radial in position. The lower side of the oral arm has a ciliated exhalent groove. The oral arms have many nematocysts. The nematocysts are also present on both the surfaces of bell and also on the manubrium and marginal tentacles.

4.21. Gastrovascular System

The mouth which is situated at the tip of the manubrium leads into a short gullet which opens into a large rectangular stomach. The stomach is produced laterally into four gastric pouches which are inter-radial in position. At the four corners of the mouth are branched four per-radial canals at right angles to each other, and between them are four inter-radial canals which are very much branched and end at the marginal lappets. Halfway between the per-radial and inter-radial canals are eight unbranched ad-radial canals, two of them arising from each gastric pouch.

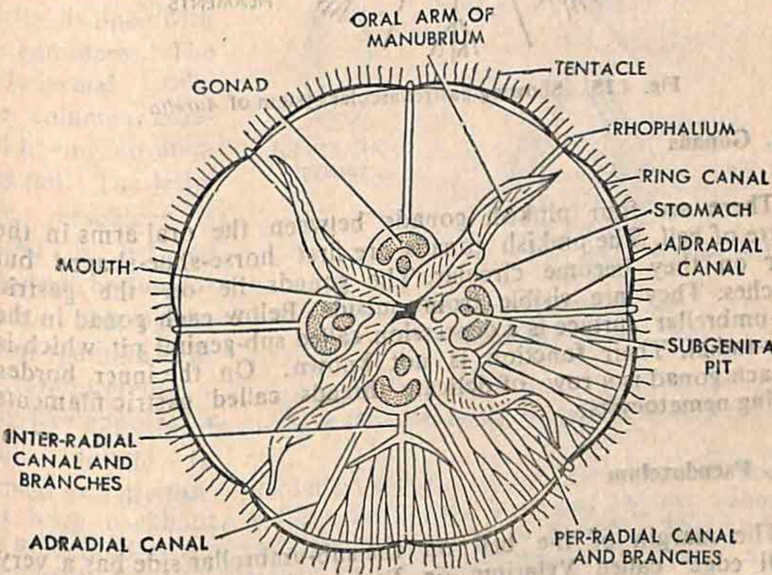


Fig 4.14. Oral view of *Aurelia*

The ad-radial canals open into a circular canal running to the margin of the bell. Thus there are 16 canals in total, all of them open into a marginal circular canal. The gullet, stomach with its gastric pouches and all the canals constitute an enteron cavity or gastrovascular system which is lined with ciliated endodermal cells. The beating of the cilia causes the circulation of the fluid. The water drawn into the mouth goes to gullet then into stomach and gastric pouches and then through the ad-radial canals to the circular canal from where it returns by the branched per-radial and inter-radial canals to the exhalent groove of oral arms and from here it goes out. Thus enteron is a gastrovascular cavity (Figs. 4.14 and 4.15).

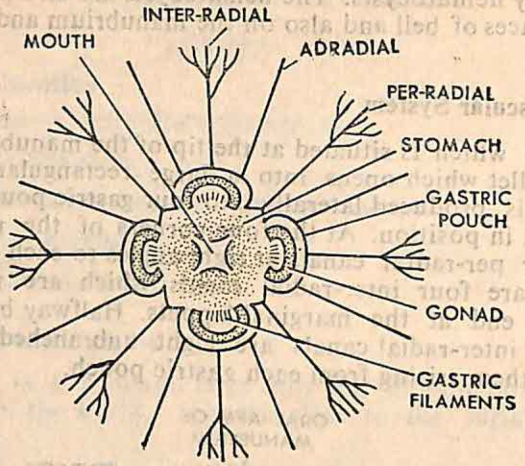


Fig. 4.15. Showing gastrovascular system of *Aurelia*

4.22. Gonads

There are four pinkish gonads between the oral arms in the centre of bell. The pinkish gonads are first horse-shoe-shaped but later on they become circular. The gonads lie on the gastric pouches. They are visible from outside. Below each gonad in the sub-umbrellar surface is a depression called sub-genital pit which is inter-radial. Their function is not known. On the inner border of each gonad is a row of delicate threads called gastric filaments bearing nematocysts.

4.23. Pseudovelum

The margin of the bell on the sub-umbrellar side has a very small edge called Velarium or Pseudovelum. The velarium of *Aurelia* has no muscle or nerve ring as is present in the velum of hydrozoan medusae. But velarium has endodermal canal.

4.24. Histology

Ex- and sub-umbrellar surfaces of *Aurelia* are covered with ectoderm having columnar epithelio-muscular cells, sensory cells, nerve cells and gland cells. The muscular part of epithelio-muscular cell is converted into contractile striated muscle fibres which are capable of rapid and rhythmic contraction which brings about the swimming of *Aurelia*. The ectodermal muscle fibres are longitudinal in tentacles, manubrium and oral arms, but in the bell they are radial. In the sub-umbrella the muscle fibres form a well-developed circular muscle band called Coronal Muscle, which is locomotory. Gullet or stomodaeum is formed by the invagination of ectoderm. But the digestive cavity is lined with the endoderm. The endodermal cells are columnar ciliated having no muscles tail. The jelly-like mesogloea is found in between ectoderm and endoderm. Mesogloea forms the main bulk of *Aurelia* giving a jelly-like appearance hence *Aurelia* is termed as **Jelly-fish.** But Jelly-fish is not a true fish because it does not have backbone, gill slits and highly developed organs. There are amoeboid cells present in the mesogloea of *Aurelia*. These cells are derived from ectoderm or endoderm and they move freely and transport food and water to the different parts of the body. Such a mesogloea having amoebocytes is called Collenchyma and it differs from mesogloea of hydrozoan medusae.

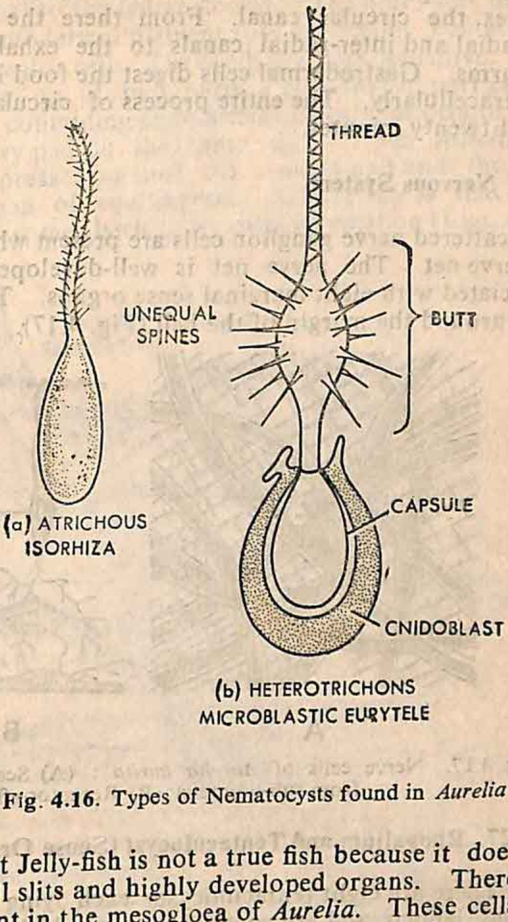


Fig. 4.16. Types of Nematocysts found in *Aurelia*

The oral arms are supplied with many nematocysts which also occur on tentacles and exumbrellar and sub-umbrellar surfaces. The nematocysts are of two types viz. (1) **atrichous isorhizas** and (2) **heterotrichus microblastic eurytcles** (Fig. 4.16).

4.25. Food and Feeding

The food of *Aurelia* consists of small marine invertebrates or small pieces of animals. The prey is paralysed by batteries of nematocysts present on tentacles. The cilia produce a current by which the water enters into the mouth and reaches the gastric cavity and then to the gastric pouches and from where by ad-radial canals reaches the circular canal. From there the water is returned by per-radial and inter-radial canals to the exhalent grooves of the oral arms. Gastrodermal cells digest the food intercellularly as well as intracellularly. The entire process of circulation of food takes about twenty minutes.

4.26. Nervous System

Scattered nerve ganglion cells are present whose processes form a nerve net. The nerve net is well-developed around the margin associated with eight marginal sense organs. There is a single nerve ring around the margin of the bell (Fig. 4.17).

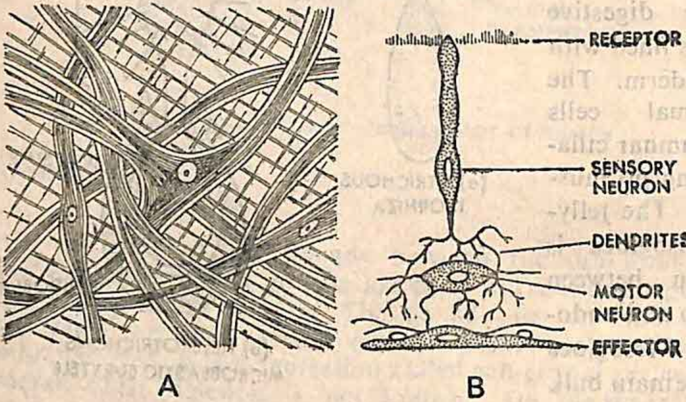


Fig. 4.17. Nerve cells of *Aurelia aurita* : (A) Scattered nerve-ganglion cells from sub-umbrella; (B) Receptor-effector system

4. 27. Rhopalium and Tentaculocyst (Sense Organs)

There are eight tentaculocysts each lying between paired marginal lappets and are covered by a hood-like process. The edge of the bell projects over the tentaculocysts as hood. The tentaculocysts are thought to be the modified tentacles and are therefore known as tentaculocysts. The cavities are continuous with the branches of radial canals. Several sense organs are localized near

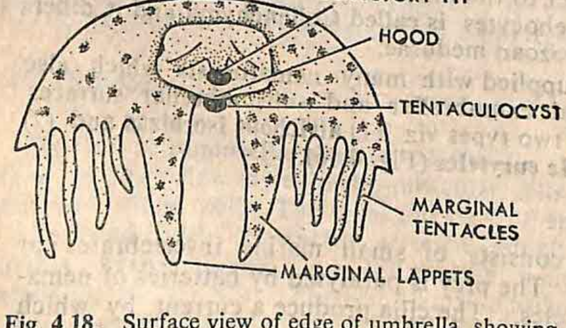


Fig. 4.18. Surface view of edge of umbrella showing position of tentaculocyst

the tentaculocyst, there are two olfactory pits one on the exumbrella and the other internal to the tentaculocyst. The outer side of the tentaculocyst has an ectodermal pigment spot or ocellus containing pigment and photoreceptor cells. The ocelli are photosensitive. The tentaculocyst is made up of two parts, a club-shaped part called statocyst or lithostyle containing endodermal calcareous otolith pigment cup and a sensory pad on the inner side. When *Aurelia* is tilted the statocyst presses against the sensory pad and the two together act as an organ of equilibrium. The result is that the *Aurelia* automatically comes back to its original position (Figs. 4.18 and 4.19).

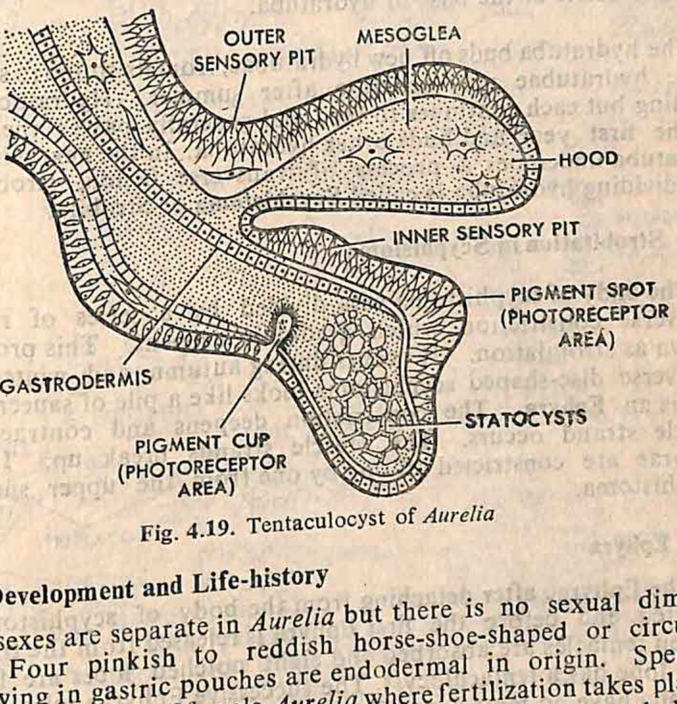


Fig. 4.19. Tentaculocyst of *Aurelia*

4.28. Development and Life-history

The sexes are separate in *Aurelia* but there is no sexual dimorphism. Four pinkish to reddish horse-shoe-shaped or circular **gonads** lying in gastric pouches are endodermal in origin. Sperms pass into the enteron of female *Aurelia* where fertilization takes place. The zygote swims in the gastrovascular canals and becomes lodged on the oral arms.

Zygote undergoes holoblastic but unequal cleavage and develops into a **blastula** having a single layer of cells and a fluid filled blastocoel. At one end of blastula invagination occurs to form a double layered **gastrula** having an outer layer of ectoderm and an inner endoderm enclosing a coelenteron which has an opening, blastopore. The ectoderm becomes ciliated and gastrula changes into **planula**. The planula of *Aurelia* differs from that of *Obelia* in the method of its formation and in having a coelenteron and blastopore. The planula becomes free from the oral arm of the female *Aurelia* and after a short free-swimming life it sinks down at the bottom of sea. Now planula larva loses its cilia, blastopore closes and the larva becomes fixed to a substratum by its aboral end.

The planula metamorphoses into a small trumpet-shaped polyp or hydratuba which has a manubrium and the blastopore opens to become the mouth. Four radial tentacles are formed and then four inter-radial and eight ad-radial tentacles arise. The endoderm of coelenteron forms four inter-radial longitudinal ridges called the gastric ridges or mesenteries. The mouth becomes square and the manubrium forms funnel-like depression called septal funnel or infundibula. These changes convert the planula into a hydratuba. A stolon arises at the base of hydratuba.

The hydratuba buds off new hydratubae, from its stolon in summer. These hydratubae may separate after summer. Hydratuba stops budding but each continues to feed and generally passes the winter of the first year and buds other hydratuba. In the next winter the hydratuba undergoes a process of transverse fission, strobilation. The dividing hydratuba is called **Scyphistoma** or Strobila.

4.29. Strobitation in Scyphisloma

The body of scyphistoma gets divided by a series of ring-like transverse constriction which gradually deepens. This process is known as strobilation. It occurs during autumn and winter. The transverse disc-shaped scyphistoma looks like a pile of saucers. Each disc is an **Ephyra**. The constriction deepens and contraction of muscle strand occurs. The muscle strands break up. Thus the Ephyrae are constricted off one by one from the upper surface of Scyphistoma.

4.30. Ephyra

The Ephyrae after detaching from the body of scyphistoma get inverted and before the first Ephyra is released from the top, each sixteen tentacles are absorbed and eight notched lobes are formed. Each lobe has a tentaculocyst. The successive Ephyrae released from Strobila have no tentacles. The Ephyra is a young medusoid form having eight notched lobes which are per-radial and inter-radial. Each lobe has two marginal lappets with a deep groove between them having a tentaculocyst. The gastric cavity grows into the lobes to form branched per-radial and inter-radial canals and then unbranched ad-radial canals are formed. Four pairs of gastric filaments form in the inter-radial mesentery. The ad-radial region which is deeply notched grows fast so that the notches are filled up. The four oral arms and marginal tentacles appear. The septal funnel becomes the sub-genital pit. Thus from an eight-rayed Ephyra a circular disc-like Jelly fish (*Aurelia*) with eight marginal lappets is formed (Fig. 4.20).

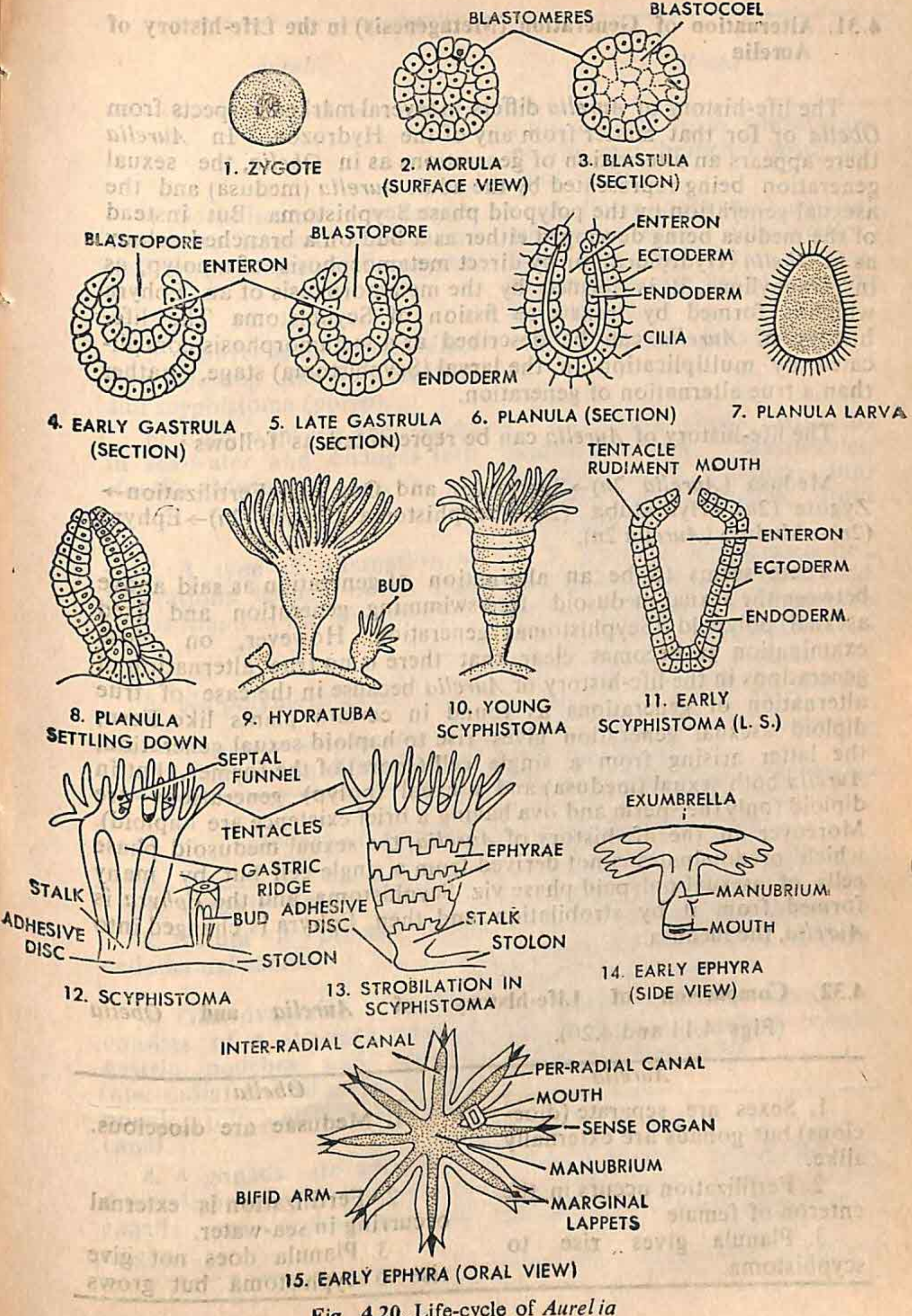


Fig. 4.20. Life-cycle of *Aurelia*

4.31. Alternation of Generation (Metagenesis) in the Life-history of Aurelia

The life-history of *Aurelia* differs in several marked respects from *Obelia* or for that matter from any of the Hydrozoa. In *Aurelia* there appears an alternation of generations as in *Obelia*, the sexual generation being represented by the adult *Aurelia* (medusa) and the asexual generation by the polypoid phase Scyphistoma. But instead of the medusa being developed either as a bud on a branched colony as in *Obelia* (Hydroidea), or by direct metamorphosis of a polyp, as in Trachylinae, it is formed by the metamorphosis of an Ephyra which is formed by transverse fission of Scyphistoma The life-history of *Aurelia* can be described as a metamorphosis complicated by multiplication in the larval (Scyphistoma) stage, rather than a true alternation of generation.

The life-history of *Aurelia* can be represented as follows :

Medusa (*Aurelia* $2n$)→Sperm (n) and Ova (n)→Fertilization→Zygote ($2n$)→Hydratuba ($2n$)→Scyphistoma (Polyp $2n$)→Ephyra ($2n$)→Medusa (*Aurelia* $2n$).

There seems to be an alternation of generation as said above between the sexual medusoid free-swimming generation and fixed asexual polypoid (Scyphistoma) generation. However, on close examination it becomes clear that there is no true alternation of generations in the life-history of *Aurelia* because in the case of true alternation of generations as found in certain plants like Fern, diploid asexual generation gives rise to haploid sexual generation, the latter arising from a single cell (spore) of the former, but in *Aurelia* both sexual (medusa) and asexual (polyp) generations are diploid (only the sperm and ova having a brief existence are haploid). Moreover in the life-history of *Aurelia*, the sexual medusoid phase which predominates is not derived from a single cell but by many cells of asexual polypoid phase viz. Scyphistoma, and the *Ephyra* is formed from it by strobilation and then Ephyra is changed into *Aurelia*, the medusa.

4.32. Comparison of Life-history of *Aurelia* and *Obelia* (Figs 4.11 and 4.20).

Aurelia	*Obelia*
1. Sexes are separate (dioecious) but gonads are externally alike.	1. Medusae are dioecious.
2. Fertilization occurs in the enteron of female.	2. Fertilization is external occurring in sea-water.
3. Planula gives rise to scyphistoma.	3. Planula does not give rise to scyphistoma but grows

Aurelia	*Obelia*
	into a stem from whose sides, polyps and branches arise forming colony.
4. Scyphistoma undergoes transverse fission or strobilation and forms a number of ephyrae.	4. Polyp does not undergo transverse fission (strobilation) and does not form ephyrae. Blastostyles give rise to medusae by budding.
5. Ephyra is an intermediate stage between *Aurelia* (medusa) and scyphistoma (polyp).	5. Ephyra stage is absent.
6. Ephyra inverts and swims in sea-water and changes into *Aurelia* (Medusa).	6. Medusa buds arise by budding from blastostyles. Medusa buds develop into medusae which detach from blastostyle.
7. A type of alternation of generations though not a true one is found in the life-history.	7. There is metagenesis i.e., alternation of generation as held by some authorities but here also altetnation of generation in **sensu strictu** is not present.
8. No polymorphism.	8. Polymorphism is present in *Obelia*

4.33. Comparison of Medusa of *Aurelia* and *Obelia*.

Medusa of *Aurelia*	Medusa of *Obelia*
1. Large in size.	1. Small in size.
2. Velum is present with endodermal canals.	2 A rudimentary velum is present but is covered on both sides by ectoderm.
3. Gastrovascular cavity consists of a stomach with 4 gastric pouches and radial, inter-radial and ad-radial canals opening into a circular marginal canal.	3. Gastrovascular cavity is simple having 4 radial canals and a marginal canal.
4. 4 gonads are present in 4 gastric pouches (one in each); gonads are endodermal in origin.	4. 4 gonads are located on four radial canals (one on each); gonads are ectodermal in origin.

Medusa of *Aurelia*	Medusa of *Obelia*
5. Gastric filaments are present in gastric pouches.	5. Absent.
6. Mesogloea is thick and has amoeboid cells and fibres.	6 Mesogloea is non-cellular.
7. There is no marginal nerve ring. Nerve fibres are concentrated radially near each sense organ.	7 There is a marginal double nerve ring present.
8. Sense organs are more complicated than those of Obelia medusa. Sense organs are statocysts with endodermal statoliths.	8. Simple sense organs in the form of statocysts, are ectodermal in origin.
9. Aurelia (medusa) is formed from ephyrae which arise from scyphistoma (polyp) by strobilation.	9. As a result of budding the medusae are formed from the blastostyles (polyps-asexually reproducing zooids).
10. Medusa (sexual) is the more dominant phase in the life-history than the polypoid phase (asexual).	10. Polypoid sedentary colonial asexual phase is more dominant than the sexual medusa phase in the life-history.

(Figs. 4.21, 4.22 and 4.23)

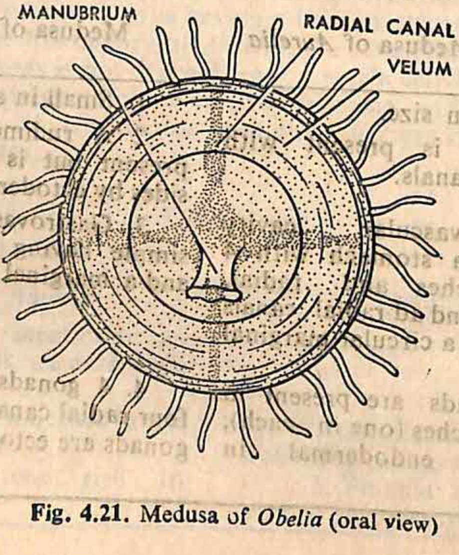


Fig. 4.21. Medusa of *Obelia* (oral view)

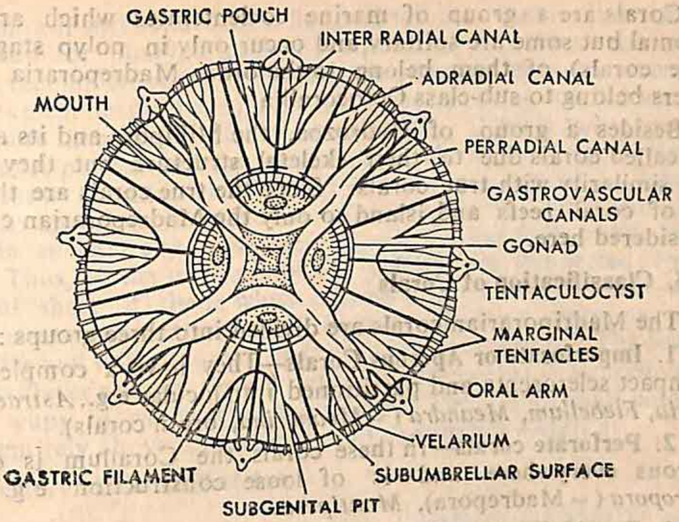


Fig. 4.22. Medusa of *Aurelia* (oral view)

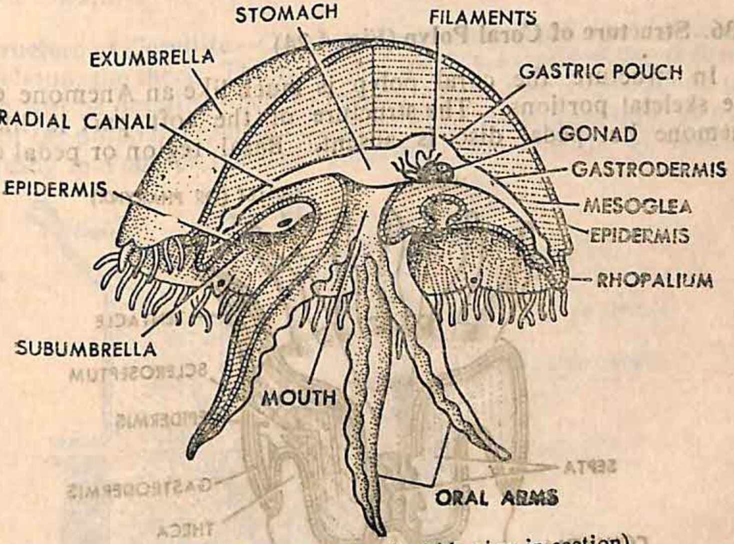


Fig. 4.23. Medusa of *Aurelia* (side view in section)

CORAL AND CORAL REEFS

CORAL :

4.34. Classification

Phylum—Coelenterata (Cnidaria)
Class—Anthozoa
Sub-class—Hexacorallia
Order—Madreporaria
Type—The true or stony corals

Corals are a group of marine coelenterates which are mostly colonial but some are solitary and occur only in polyp stages. Most (true corals) of them belong to the order Madreporaria butsome others belong to sub-class Octocorallia.

Besides a group of Hydrozoa, the Millipora and its allies also are called corals due to their skeletal structure but they have no real similarity with true corals. Since the true corals are the builders of coral reefs and island so only the Madreporarian corals are considered here.

4.35. Classification of Corals

The Madriporarian corals are divided into three groups :

1. **Imperforate or Aporous Corals**—They have a complete theca, compact sclerosepta and partitioned into loculae e.g., *Astraeid* corals. *Favia, Flebellum, Meandra* (= *Meandrina*, brain corals).

2. **Perforate corals**—In these corals the Corallum is extremely porous everywhere and is of loose construction e.g. Porites, *Acropora* (= Madrepora), *Montipora.*

3. **Fungid Corals**—These may be either perforate or imperforate e.g., *Fungia.*

4.36. Structure of Coral Polyp (Fig. 4.24)

In structure the coral polyp is much like an Anemone except the skeletal portions. The structure of the soft part is like sea anemone but pedal disc is absent. Basal region or pedal disc is occupied by skeletal cup There is no oral cone. Mouth is situated in the middle of the oral disc. A typical oral disc with tentacles on typical hexamerous plan is present. Tentacles are simple and of moderate length ending in a terminal knob of nematocysts. A

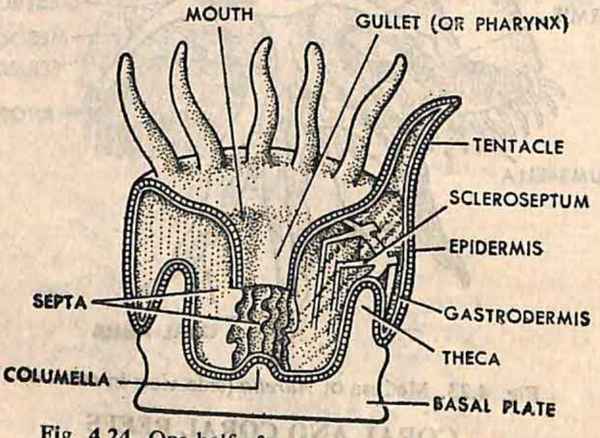


Fig. 4.24. One half of a simple coral polyp showing relationship of soft parts to theca (corallite)

circular mouth surrounded by a flat peristomium leads into short stomodaeum or pharynx devoid of siphonoglyph. There are complete and incomplete septa or mesenteries arranged in cycles arranged on the typical hexamerous plan. Coral polyp being small does not possess more than three cycles of mesenteries. Usually two pairs of directives are present and there are ostia on the septa. The polyps of colonial corals are all interconnected but the attachment is lateral rather than aboral, as in hydroids. The column wall folds outward above the skeletal cup and connects with similar folds of adjacent polyps. Thus, all the members of the colony are connected by a horizontal sheet of tissue which represents a fold of the body-wall and so it contains an extension of the gastrovascular cavity as well as an upper and lower layer of endoderm and ectoderm. The lower ectodermal layer secretes the part of the skeleton that is located between the cups in which the polyps lie. The living coral colony thus lies entirely above the skeleton and completely covers it.

4.37. Structure of Coral Skeleton

The skeleton of a colony is termed as **Corallum** and that of each polyp a **Corallite**.

Structure of Corallite—Coral polyps remain fixed in a cup-like exoskeleton, the **theca**. The theca and the other parts of the skeleton (which will be described below) remain wholly to the outside of the body of the polyp but remain in contact with its ectoderm through out. According to **Voucoch** the skeleton of coral is made up of calcium

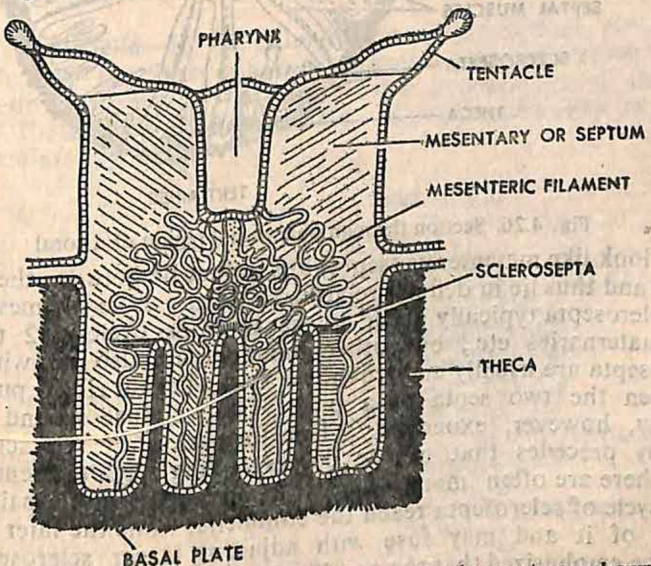


Fig. 4.25. V. S. through a coral in its theca (3 sclerosepta are shown)

carbonate and is formed by the precipitation of Calcareous crystals in a colloidal matrix secreted by the ectodermal cells outside the body wall for the protection of the polyp.

A typical polyp coral has the following parts :

1. **Basal Plate**—A basal plate lies between the polyp and the substratum. It is the bottom of the cup.

2. **Theca**—It is a cuplike structure from which the polyp projects out and into which it can be retracted.

3. **Sclerosepta**—These are calcareous ridges or partitions arranged vertically or projecting radially inwards and are connected at the base by basal plate and at the side with the cup-like theca. They look like mesenteries (septa) but in fact lie between the mesenteries and thus lie in definite relation to them. Like the mesenteries, the sclerosepta typically occur in hexamerous cycles, 12 tertiaries 24 quaternaries etc., but other numbers are also met with. The sclerosepta are usually endocoelic i.e. each skeletal ridge pushes up between the two septa of a pair. The original second cycle is usually, however, exocoelic. The formation of the sclerosepta usually precedes that of the corresponding septa (mesentery) and thus there are often more sclerosepta than mesentery pairs. The first cycle of sclerosepta reach the columella, while the later ones fall short of it and may fuse with adjacent larger sclerosepta. It may be emphasized that the corallite lies entirely outside the body

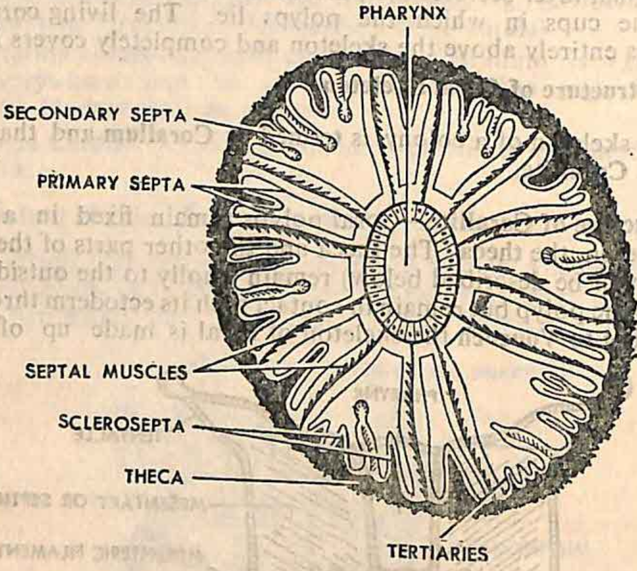


Fig. 4.26. Section through pharyngeal region of a coral

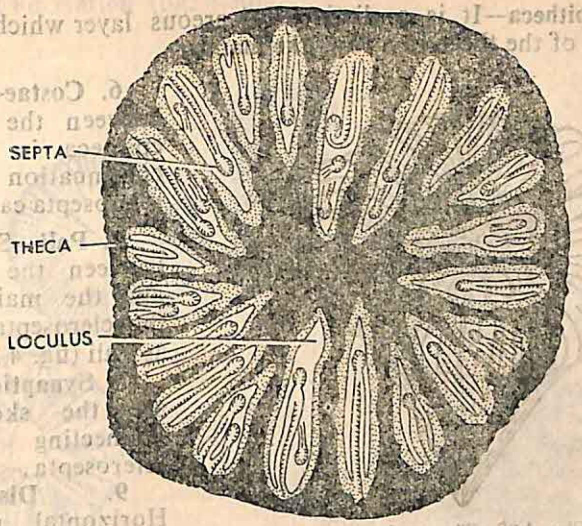


Fig. 4.27. Section through the base of a coral showing loculi with enclosed septa

of the polyp and the polyp base is pushed into ridges over the sclerosepta and goes down into blind pockets (loculi) between sclerosepta and mesentery (fig. 4.27).

The sclerosepta are commonly spiny or thorny with jagged or toothed upper edges.

4. **Columella**—It is a pillar-like irregular central skeletal mass which may be either an independent outgrowth from the basal plate or are formed by the union of the central ends of the sclerosepta, then called **pseudocolumella**. The columella may be solid or trabeculate (fig. 4.28).

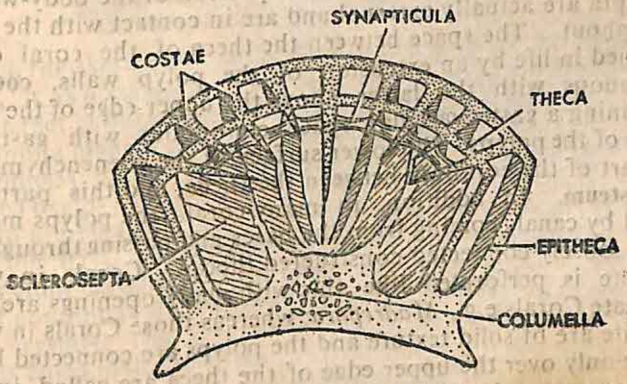


Fig. 4.28 Half of a coral skeleton

5. **Epitheca**—It is a distinct calcareous layer which surrounds the base of the theca in a ring-like manner.

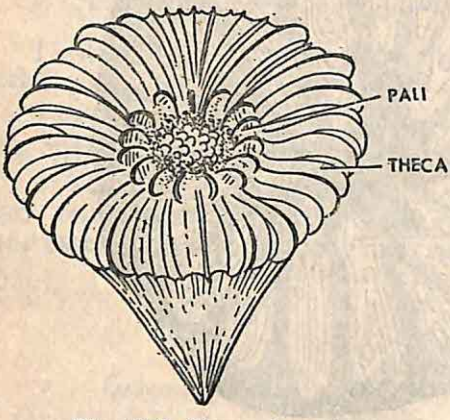


Fig. 4.29. Theca of a solitary coral showing pali

6. **Costae**—The space between the theca and epitheca is crossed by continuation of the sclerosepta called costae.

7. **Pali**—Small ridges between the columella and the main parts of the sclerosepta are termed as Pali (fig. 4.29).

8. **Synapticula**—These are the skeletal bars connecting adjacent sclerosepta.

9. **Dissepiments**—Horizontal plates between sclerosepta are known as dissepiments. These are of small extent.

10. **Trabeculae**—When the horizontal plates between sclerosepta are large and extend completely across the corallite they are termed as trabeculae.

In living condition, the polyp fills the whole of the interior of the corallite and projects beyond its edge. The proximal portion of its body-wall is in contact with the theca which is a product of the epidermis. The free part of the body-wall of polyp is folded over the edge of the theca so as to cover its distal portion. Each skeletal septum is covered by an inturned portion of the body-wall. Thus the septa are actually external and are in contact with the epidermis throughout. The space between the theca of the coral colonies is occupied in life by an extension of the polyp walls, **coenenchyme** continuous with the latter above the upper edge of the theca and containing a gastrovascular space continuous with gastrovascular cavity of the polyps The lower surface of the coenenchyme secreates the part of the corallum between the theca, and this part is called **coenosteum**. In addition, in many corals, the polyps may be connected by canals coming from the bases and passing through openings in the loosely connected constructed thecae. Corals in which the corallite is perforated like this with many openings are termed as perforate Corals e.g., *Madrepora*; whereas those Corals in which the corallite are of solid texture and the polyps are connected by coenenchyme only over the upper edge of the theca are called imperforate or a porous corals e.g. *Flabellum*, *Astraea* etc.

4.38. Coral Formation. (fig. 4.30).

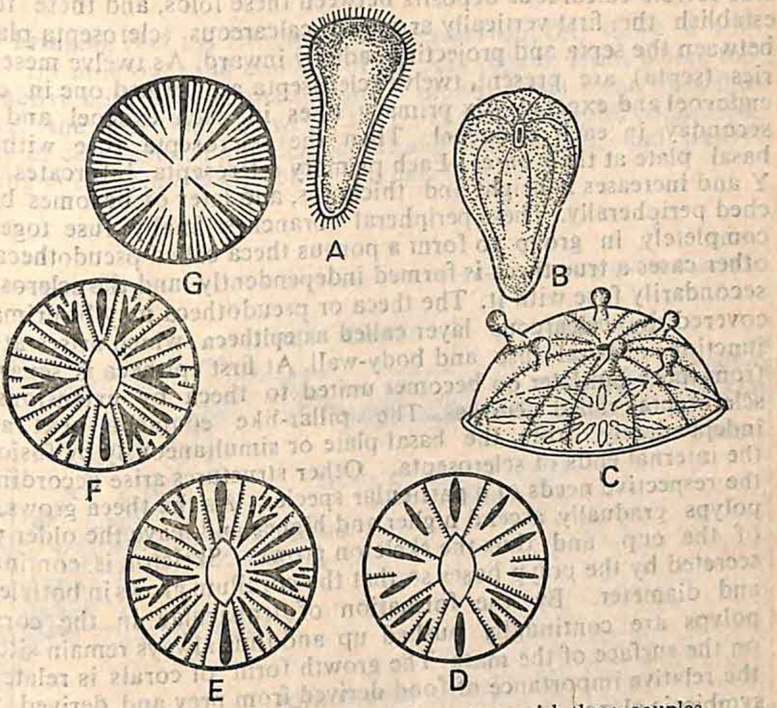


Fig. 4.30, Development: A. planula; B. later stage with three couples of septa; C. young polyp after attachment with six tentacles; 12 septa, basal plate and 2 cycles of sclerosepta appearing; D. stage similar to C with two cycles of sclerosepta; E. next stage, secondary sclerosepta forked, tertiary sclerosepta appearing; F. next stage, tertiary sclerosepta fused with secondary ones; G. final arrangement of sclerosepta

Though the skeleton of an adult coral polyp appears to be within its body, it is actually an external structure. This morphologically significant fact is born out clearly by their embryology. The ciliated free swimming **planula** larva has no skeleton. Then the larva becomes fixed, tentacles appear and the fixed larva (which has now changed into polyp) begins to secrete exo-skeleton. The first part of a coral skeleton to appear is a ring-shaped deposition of calcium carbonate between the basal epidermis of the polyp and the surface of attachment. Calcium carbonate is in the form of numerous spheroidal masses of concentric structures and each mass is built up of numerous rhombic crystals. The ring soon develops into a disc called basal plate. The basal plate increases in size subsequently. Then twelve radially arranged folds of septal mesenteries arise from the basal body-wall either all simultaneously or six primary and six secondary.

These project into the Coelenteron. The ectoderm of the septal folds secrete calcareous deposits between these folds, and these folds establish the first vertically arranged calcareous sclerosepta placed between the septa and projecting radially inward. As twelve mesenteries (septa) are present, twelve sclerosepta are formed one in each endocoel and exocoel—six primary ones in each exocoel and six seconday in each endocoel. Then the selerosepta fuse with the basal plate at their bases. Each primary selerosepta bifurcates like Y and increases in height and thickness, and later on becomes branched peripherally. These peripheral branches finally fuse together completely in group to form a porous theca called pseudotheca. In other cases a true theca is formed independently and the sclerosepta secondarily fuse with it. The theca or pseudotheca may be primarily covered by calcareous layer called as **epitheca** which arises at the junction of basal disc and body-wall. At first epitheca is separated from theca but later on becomes united to theca by extensions of sclerosepta called **costae**. The pillar-like coumella next arises independently from the basal plate or simultaneously by fusion of the internal ends of sclerosepta. Other structures arise according to the respective needs of a particular species.. As the theca grows, the polyps gradually ascend higher and higher and leave the older parts of the cup and thus the skeleton grows. Skeleton is continually secreted by the polyp bases so that the corallum grows in both length and diameter. By the formation of trabaculae in the corallite polyps are continually pushed up and thus always remain situated on the surface of the mass The growth form of corals is related to the relative importance of food derived from prey and derived from symbiotic algae.

4.39. Coral Reefs

A coral-reef is a ridge or mound of lime stone the upper surface of which is near the surface of the sea and which is formed of calcium carbonate by the action of organisms chiefly corals (**Vaughan** 1917). Though the reefs are built by stony corals but other organisms such as foraminifera, millipora, tubipores, heliopores, the molluscs, echinoderms, some coralline, algae and sponges contequeute together in the formation of compact structure, the coral reefs. The coral reefs are formed by incrusting their skeletal parts on the deposited lime. Coral reefs composed of multiple of organisms vary in shape and colour. The Zooxanthelae is responsible for the rich colouration of corals, which may be brown, yellow, or green. The reef building corals require warm, shallow waters and consequently are limited to continental island shores in tropical and sub-tropical zones. They cannot tolerate temperatures below 18°C and thy flourish nicely only above 22°C. Consequently their distribution is limited to the zone existing between about 28°C on either side of the equator. They rarely remain alive at a depth greater than 4 fathoms.

Coral reefs are of three kinds—(1) Fringing reefs, (2) Barrier reefs and (3) Atolls (figs. 4.35 and 4.36).

1. **Fringing reef :** A fringing reef extends from the shore a few feet to 1/4 mile out and consists of the reef edge or front where the most active coral growth occurs, and a slightly lower some what flat surface, the **reef flat**, between the front and the shore, composed largely of coral sand, mud, dead coral and other debris, and partly of living coral colonies and other animals (fig. 4.31).

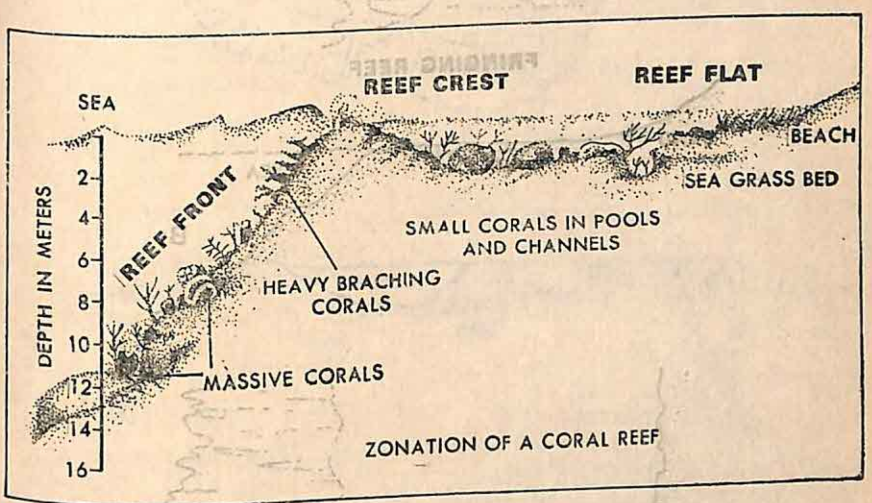
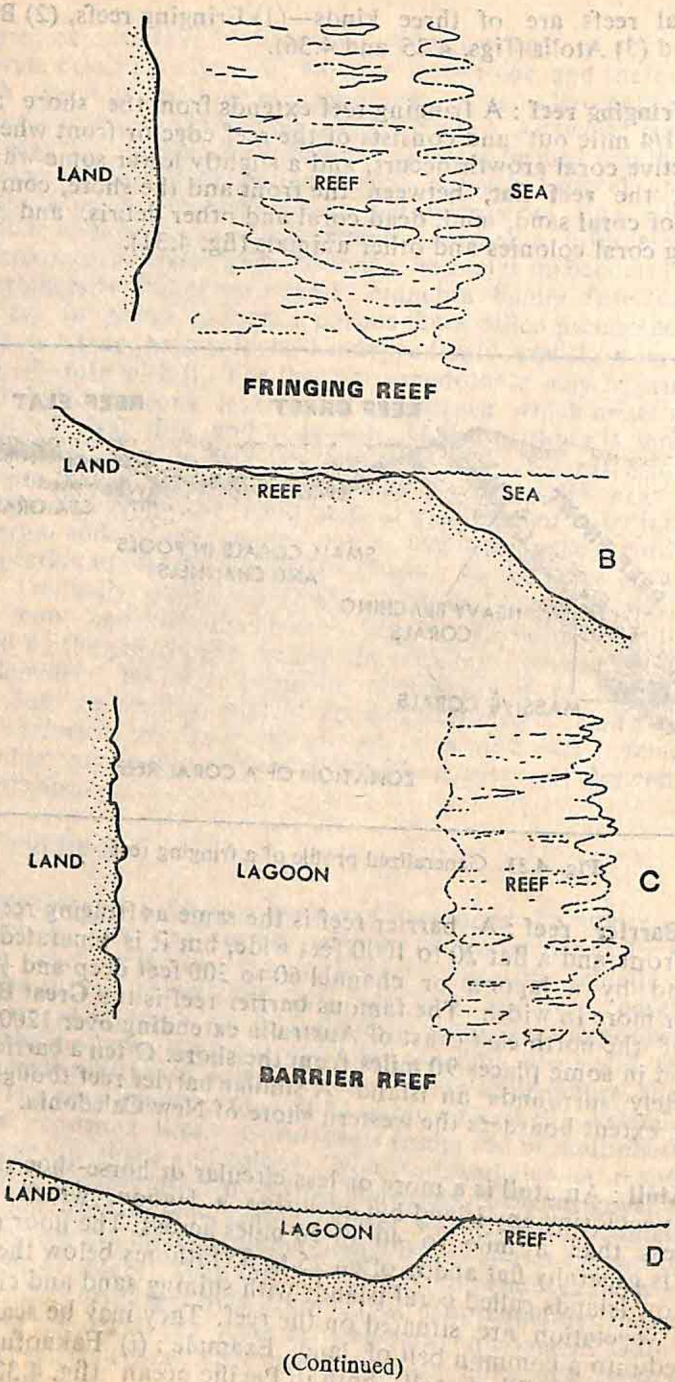


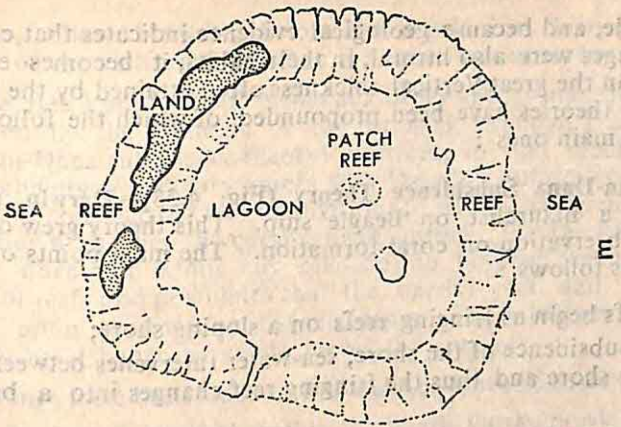
Fig. 4.31. Generalized profile of a fringing reef

2. **Barrier reef :** A barrier reef is the same as fringing reef with a reef front and a flat 20 to 1000 feet wide, but it is separated from the land by a lagoon or channel 60 to 300 feet deep and $\frac{1}{2}$ to 10 miles or more in width The famous barrier reef is the **Great Barrier Reef** of the north east coast of Australia extending over 1200 miles long and in some places 90 miles from the shore. Often a barrier reef completely surrounds an island. A similar barrier reef though of a smaller extent boarders the western shore of New Caledonia.

3. **Atoll :** An atoll is a more or less circular or horse-shoe shaped reef not enclosing any island but enclosing a lagoon, which varies from less than a mile to 40 or 50 miles across. The floor of the lagoon is generally flat and is often 25 to 35 fathoms below the surface. Low islands called coral islands with shining sand and characteristic vegetation are situated on the reef. They may be scattered or united into a common belt of land. Example : (i) Fakaofu atoll (union island). (2) Bikni atoll—both in Pacific ocean (fig. 4.32).


LAND
REEF
SEA
FRINGING REEF
LAND
REEF
SEA
B
LAND
LAGOON
REEF
C
BARRIER REEF
LAND
LAGOON
REEF
D

(Continued)



ATOLL

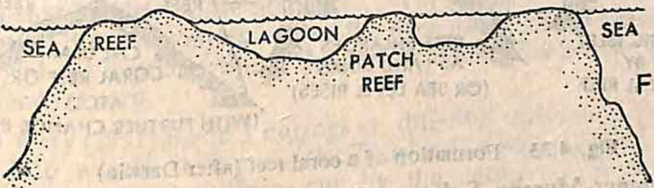


Fig. 4.32. Types of reefs : A and B—fringing reef, surface view and in section; C and D—barrier reef; E and F—atoll

However, none of the reef types are like man-made continuous wall but is broken up into many reefs and islands by passages, the larger of which may be drowned valley, sunk below the sea by land submergence or rise in sea level. The lagoons usually contain inner island, or islands, and reef, etc. The flats are more or less exposed at the lowest tides. The reef front is exposed to forceful waves which knock off big and small fragments of the reef and heaves them up on the flat behind the reef edge. The reef front first of all slopes gradually but after about 200 feet the slope becomes very steep.

4.40. Theories to Explain Great Vertical Thickness of Coral Reef.

Since the present reef-building corals do not grow below 150 feet at the outside, and because geological evidence indicates that corals of the past ages were also littoral, in their habits, it becomes essential to explain the great Vertical thickness often attained by the coral reefs. Many theories have been propounded, of which the following four are the main ones :

1. **Darwin-Dana Subsidence Theory** (Fig. 4.33)—**Darwin** spent 5 years as a naturalist on 'Beagle' ship. This theory grew out of Darwin's observation on coral formation. The main points of this theory are as follows :

(i) Reefs begin as fringing reefs on a sloping shore;

(ii) by subsidence of the shore, sea-water intervenes between the reef and the shore and thus the fringing reef changes into a barrier reef;

(iii) if the land is an island, the barrier becomes an atoll.

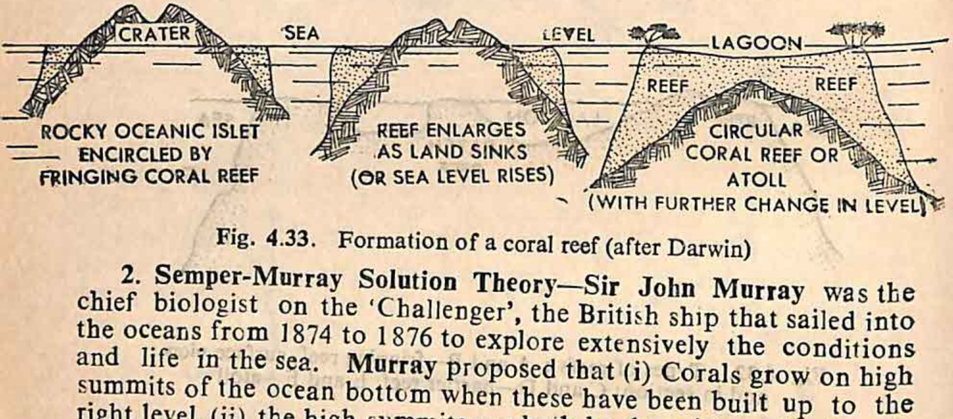

CRATER
SEA
LEVEL
LAGOON
REEF
REEF
ROCKY OCEANIC ISLET ENCIRCLED BY FRINGING CORAL REEF
REEF ENLARGES AS LAND SINKS (OR SEA LEVEL RISES)
CIRCULAR CORAL REEF OR ATOLL
(WITH FURTHER CHANGE IN LEVEL)

Fig. 4.33. Formation of a coral reef (after Darwin)

2. **Semper-Murray Solution Theory**—**Sir John Murray** was the chief biologist on the 'Challenger', the British ship that sailed into the oceans from 1874 to 1876 to explore extensively the conditions and life in the sea. **Murray** proposed that (i) Corals grow on high summits of the ocean bottom when these have been built up to the right level, (ii) the high summits are built by deposition of sediments and (iii) barrier reefs and atolls are formed due to better growth of corals at the reef edge and through solution of the inner coral rock. This theory is now not accepted at all.

3. **Submerged Bank Theory**—According to this theory which is supported by many recent students of his subject, coral formation grows on flat pre-existing surfaces, during or after the submergence of such surfaces.

4. **Daly-Glacial-Control Theory**—The main points of this theory are as follows : (i) During the last glacial period much water of the ocean turned into ice forming glaciers due to very low temperature and thus the level of the ocean was lowered by 60 to 70 metres below the present level. (ii) Various terraces were then cut or islands levelled by wave action. (iii) Later, with the rising, temperatures, corals began to grow upon these platforms and kept pace with the rising sea-level as the ice melted.

This theory explains nicely about the uniform depth of coral lagoons, whose bottoms, below the debris since deposited, would consist of the platforms cut when the ocean was at its low level.

Theories 3 and 4 supplement each other and at present are most favoured by the students of the problem, although Darwin's idea (Darwin-Dana subsidence theory) continues to find much support. The submergence theory agrees with Darwin's subsidence theory in that both consider the reef foundations to be now at greater depths than they were when the coral growth started. But the submergence theory does not admit any relationship between that the various kinds of reefs and postulates that the barrier reef and atoll have grown upon pre-existing flat platforms. The atolls are considered to have been shaped by winds, waves and currents.

Borings have been made to find out the truth of these theories.

(i) Boring of Funafuti atoll in the South Pacific north of Fiji was made in 1904 by an expedition of the Royal Society of London. The boring was 3 inches to 5 inches in diameter and went up to 1114 feet without reaching the reef base. Twenty eight genera of reef-building corals were discovered, 22 of which are now living on the reef in that locality above 60 metres. The material obtained from the boring did not contain any of the deep water corals living in that locality at the depth to which the boring went. This finding supports subsidence theory.

(ii) **Cary** (1931) made 3 borings at different distances from the shore into a reef in Samoa (Pacific island) and concluded that the reef rested on a level platform cut by the action of waves. This supports the glacial control theory.

(iii) The Great Barrier Reef Committee made two borings, one in 1928 and the other in 1938 on the Great Barrief Reef. Both borings gave the same result that the coral material extended out only to 400 to 450 feet and below this there was nothing but shore sand containing shells of various animals. There was no evidence of any underlying platform. Therefore this finding also supports Darwin's subsidence theory. Thus Darwin's subsidence theory applies of many reefs but some reefs may have been laid down on pre-existing platforms.

present day reefs grow 5 to 200 mm. per year, and it is estimated that all existing reefs could have been formed in 10,000 to 30,000 years.

Some important facts about reefs—Tropical storms can modify the reefs very much. Quarrying can also damage reefs as in India, where in 1971 **Pillai** has estimated that nearly 250 cubic metres of reefs material are removed per day for use in the production of cement, calcium carbide, calcium carbonate etc. Recently much concern has been expressed for the safety of some oceanic islands and their reef food chains because some reefs are being destroyed by ever increasing population of the Crown-of-thorns starfish, *Acanthaster planei*. These starfishes feed upon the living coral and have caused much reef destruction in some parts.

4.41. Significance of Coral reefs

1. Coral skeletons from ancient reefs are useful for interpretation of environment of the past.

2. The studay of coral reefs has significance to the petroleum geologist. They are important reservoirs of petroleum.

CLASS III—ACTINOZOA

Sea-Anemone (*Metridium*)

4.42. Classification

Phylum—Coelenterata (cnidaria)
Class—Actinozoa (Anthozoa)
Sub-class—Hexacorallia
Order—Actiniaria
Genus—*Metridium*

4.43. Habits and Habitats

Sea-anemones inhabit coastal waters throughout the world but are specially abundant in tropical oceans. They are commonly attached to rocks, shells and submerged woods by basal disc, and some forms burrow in mud or sand. The shape of the body is usually related to the habitat in which the sea-anemone lives. They are carnivorous. Some sea-anemones are commensal on the shells of hermit-crab.

4.44. External Structure (fig. 4.34)

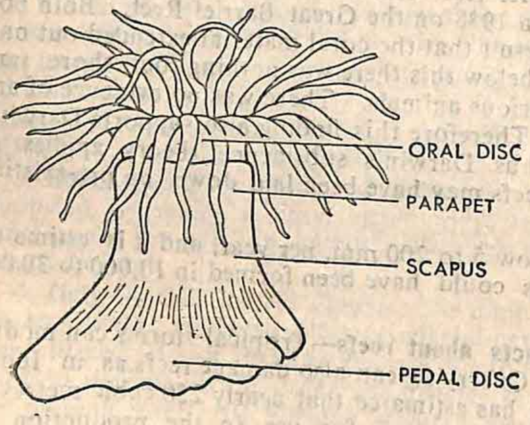


Fig. 4.34. Young specimen of *Metridium*

Sea - anemones are polyps. Sea-anemones have the form of a cylinder, their diameter exceeds their height. The length is 1·5 to 5 cm and the diameter is usually 3 cm. They are green or red in colour. They have flower-like appearance and are of brilliant beautiful colour.

The body is divisible into three parts :

(i) Broad sole-like base which is sharply separated from (ii) an upright cylinder wall, column which at its upper end has (ii) the oral disc.

(i) **Base**—This is the broad surface by which sea-anemone attaches itself to some substratum. The base is separated from the column by a constriction called **limbus.** It expands into a circular **pedal disc** by which sea-anemone can attach itself to stone. However, according to various modes of life the base can assume these different shapes (a) it may be curved round to grasp the ball of mud in some deep water forms, (b) in littoral, commensal forms, it may be drawn into a lobe on each side, the lobes are used to wrap round the stems or shells of living animals, (c) it may be simply rounded or pointed in forms inhabiting soft bottoms, (d) in tropical forms e.g. in *Minyadida* the pedal disc becomes a float that is, it becomes curved into a sac filled with a chitinous net work. The base may be pierced by one or several pores.

(ii) **Column**—The cylindrical portion which lies in between the oral disc and the base is known as **Column.**

The junction of the oral disc and the column is called the **margin** and it may be marked by a groove. The surface of the column is beset with adhesive warts or papillae by whose secretions the animal gets the stones, sands and shells attached to its body surface and gets completely hidden from view. The wall of the column may vary from thin transparent to thick leathery condition. The column right from the base to margin may be of the same texture but in other genera e.g. *Phellia* etc. may be differentiated into an upper short region the **capitulum** and a lower thick walled region, the **Scapus.** In *Metridium* the scapus just before joining the capitulum stands up as a distinct fold, the **collar** or **parapet,** and a groove called **fosse** results between the collar and base of the capitulum. Irrespective of the presence or absence of the capitulum the upper part of the scapus may be differentiated into a short region, the **scapulus.** Just below the margin or at the lower boundry of capitulum there is the marginal **sphincter**. This acts to close the margin or upper end of the scapus over the retracted oral disc or capitulum (when present) when sea-anemone contracts. In sea-anemone having parapet, the sphincter is in the wall of the fosse. The wall of the column presents a variety of special structures or protuberances which may be ornamented with adhesive or protective papillae. Thus they cover themselves by sands and stones. These papillae may be arranged in rows. In some of the sea-anemones the column wall is provided with a number of pores, called as **cinclides** through which **acontia** protrude out. They also serve for the emission of water when the column contracts.

(iii) **Oral disc**—It is the upper convex free end of the body having an oval or slit-like mouth in the centre. It is separated from the nearest tentacles by a space, the **peristome.** Springing from the oral disc and encircling the mouth are numerous hollow short and conical tentacles, forming a sort of crown.

4.45. Internal Structure

The longitudinal and transverse section of *Metridium* show the following structures :

Internal Cavity—It is divisible into 3 regions (1) Pharynx or gullet or stomodaeum (2) Stomach or Coelenteron or gastrovascular cavity, (3) intermesenteric chambers.

Gullet or Stomodaeum—The mouth leads into a strong flattened cylinder called pharynx, gullet or Stomodaeum. It hangs down into the body and terminates in free edge. At each end there is a descending flap or lappet. The gullet is lined by ectoderm (fig. 4.35).

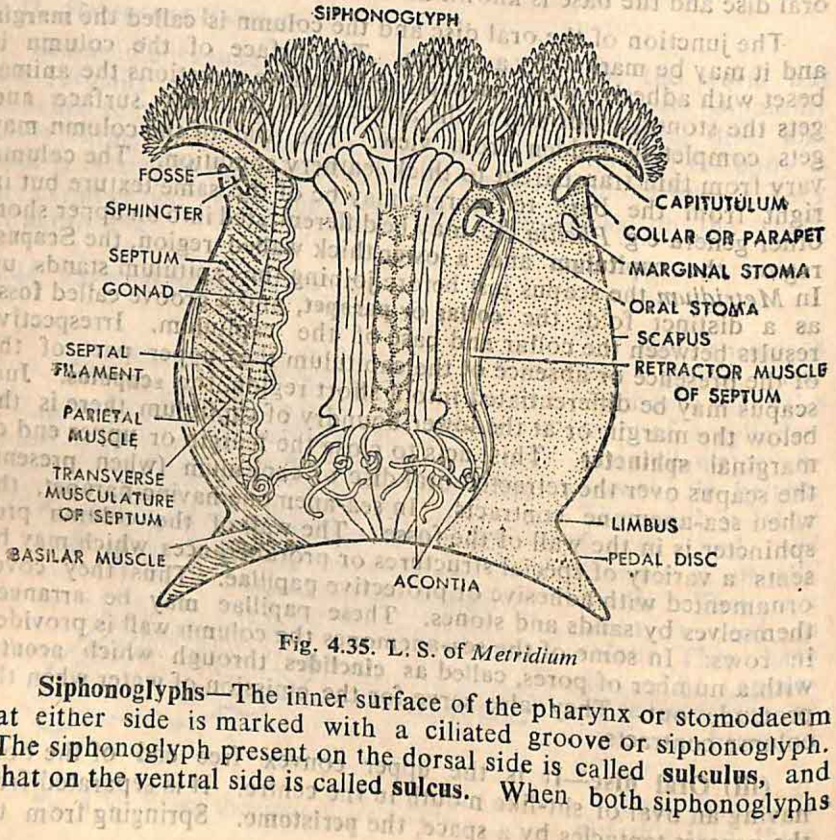


Fig. 4.35. L. S. of *Metridium*

Siphonoglyphs—The inner surface of the pharynx or stomodaeum at either side is marked with a ciliated groove or siphonoglyph. The siphonoglyph present on the dorsal side is called **sulculus**, and that on the ventral side is called **sulcus**. When both siphonoglyphs are present the animal is called diglyphic; such forms are biradial. When only one siphonoglyph is present (it is usually present on the ventral side), the animal is known as monoglyphic. Both monoglyphic and diglyphic individuals occur in *Metridium*. Cases of anemones are on record with 3 to 10 or more siphonoglyphs. All such irregularities probably result from asexual modes of reproduction or regeneration after injury. The cilia of the cells of siphonoglyphs beat constantly whereby a continual stream of water is carried into the body cavity through these siphonoglyphs, thus maintaining a constant supply of oxygenated water.

Gastrovascular Cavity—The gullet opens below into the gastrovascular cavity; stomach or coelenteron. It is divided into six radial compartments (which lie between the gullet or pharynx and body wall) by primary septa or primary mesenteries. The water passes from one chamber to another through pores in these mesenteries. The radial chambers open into a common basal cavity.

Intermesenteric Chambers—The gastrovascular cavity thus becomes, divided by mesenteries into a number of radially arranged cavities, the intermesenteric chambers (Figs. 4.36 and 4.37).

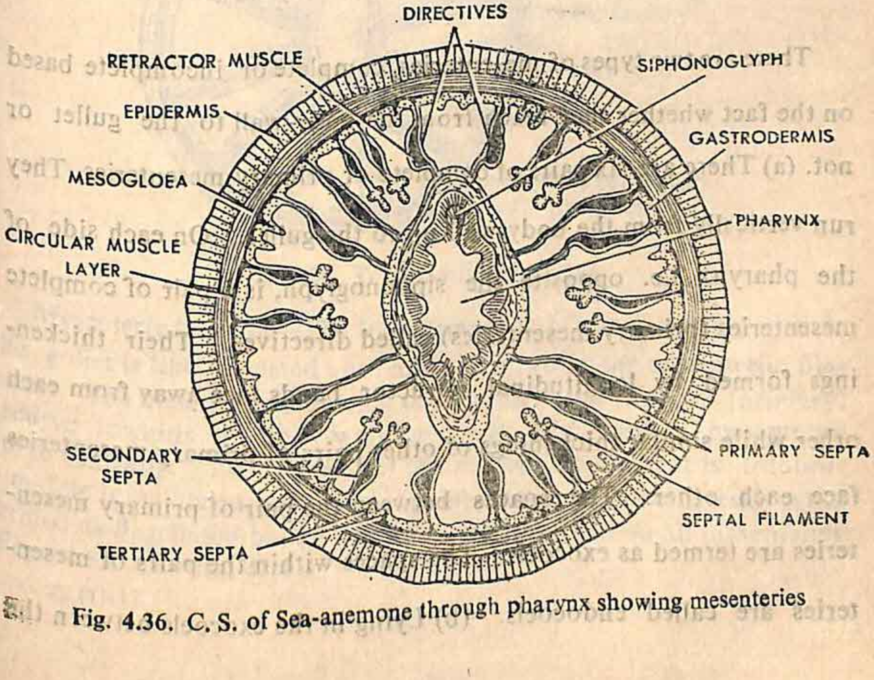


Fig. 4.36. C. S. of Sea-anemone through pharynx showing mesenteries

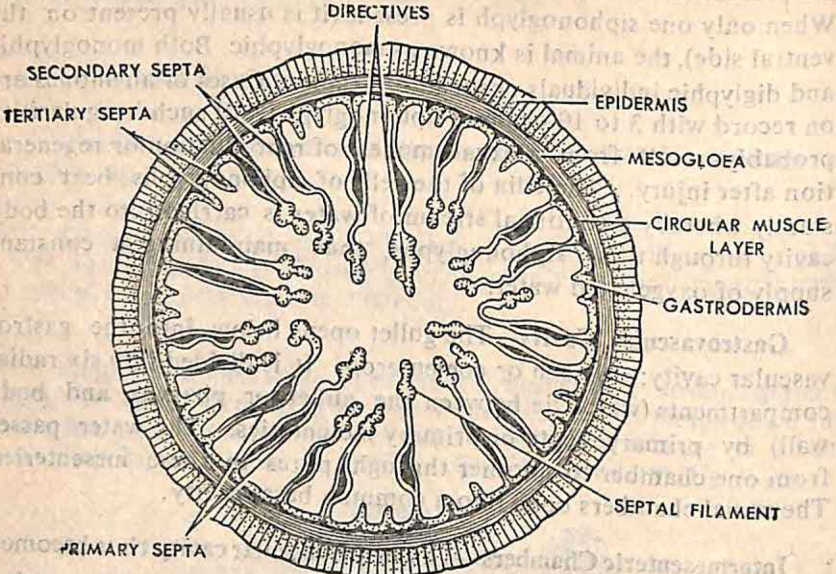


Fig. 4.37. C. S. of Sea-anemone below pharynx showing mesenteries

4.46. Mesenteries

There are two types of mesenteries, complete or incomplete based on the fact whether they reach from the body-wall to the gullet or not. (a) There are six pairs of complete or primary mesenteries. They run vertically from the body-wall up to the gullet. On each side of the pharynx i.e. opposite the siphonoglyph, is a pair of complete mesenteries (primary mesenteries) called directives. Their thickenings formed by longitudinal retractor bands face away from each other while similar thickenings of other pairs of primary mesenteries face each other. The spaces between the pair of primary mesenteries are termed as exocoels. The spaces within the pairs of mesenteries are called endocoels. (b) Lying in the exocoels between the primary mesenteries are six pairs of incomplete secondary mesenteries extending only part of their way from the body-wall to the gullet. Their thickenings face each other. (c) Lying in the exocoels between the primary and secondary mesenteries are twelve pairs of incomplete tertiary mesenteries. They are hardly more than ridges on the body-wall.

4.47. Histology of Mesenteries

The mesenteries are made up of two layers of gastrodermis enclosing a central layer of mesoglea between them. The retractor muscle, transverse muscle and parietal muscles are present in the mesentery. The gonads (testes and ovaries) occur as thickened bands in the substance of the mesenteries, a short distance from the edge (Fig. 4.38).

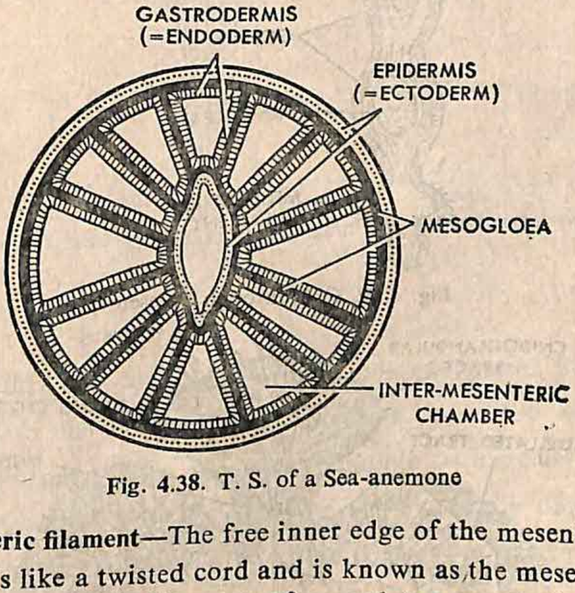


Fig. 4.38. T. S. of a Sea-anemone

Mesenteric filament—The free inner edge of the mesentery below the gullet is like a twisted cord and is known as the mesenteric filament. The mesenteric filaments of complete mesenteries (primary) recurve towards the body-wall but those of incomplete mesenteries curve centrally. The free end of the mesenteric filament is trilobed-a middle lobe, called as cnidoglandular band and two lateral lobes termed as flagellated bands. Middle lobe is present on all mesenteries (Figs. 4.39, 4.40 and 4.41).

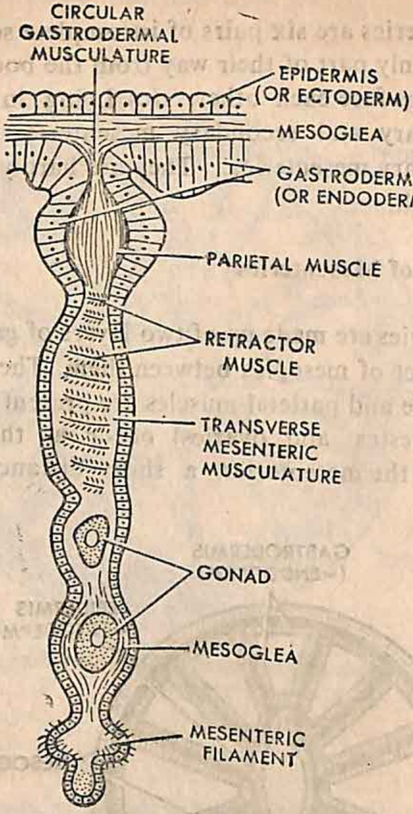


Fig. 4.39. C. S. through a mesentery

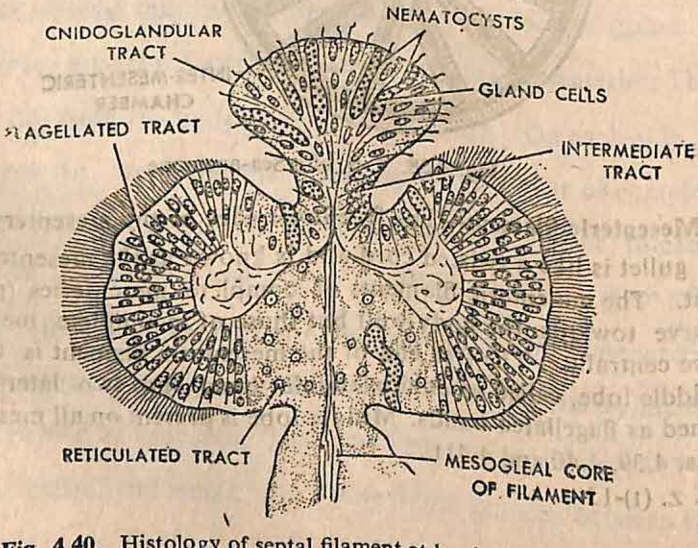


Fig. 4.40. Histology of septal filament at levels through the pharynx

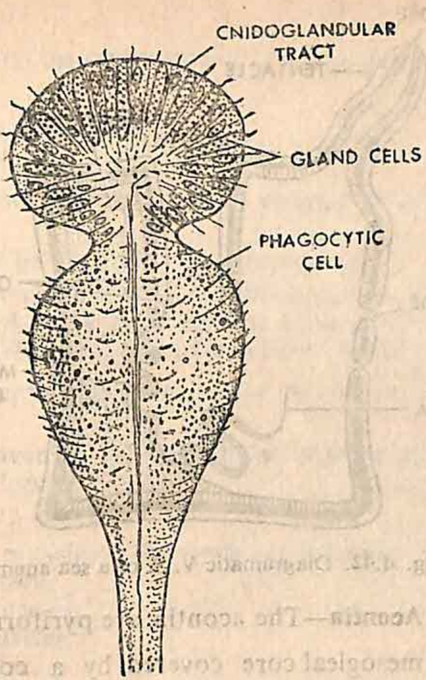


Fig. 4.41. Histology of a septal filament in levels below the pharynx

Acontia—In many sea-anemones, the mesenteric filaments are produced into slender threads—the **acontia** from the middle lobe. The acontia may come out through mouth or apertures (cinclides) on the body-wall (Fig. 4.42) when the sea-anemones contract. The acontia bear nematocysts and gland cells. They serve for offence and defence. The middle lobe has gland cells and nematocysts which produce digestive enzymes. The lateral lobes are composed of ciliated cells which help in water circulation. The mesenteric filaments at the level through the pharynx have nematocysts, gland cells and phagocytic cells. The mesenteric filaments help in digestion.

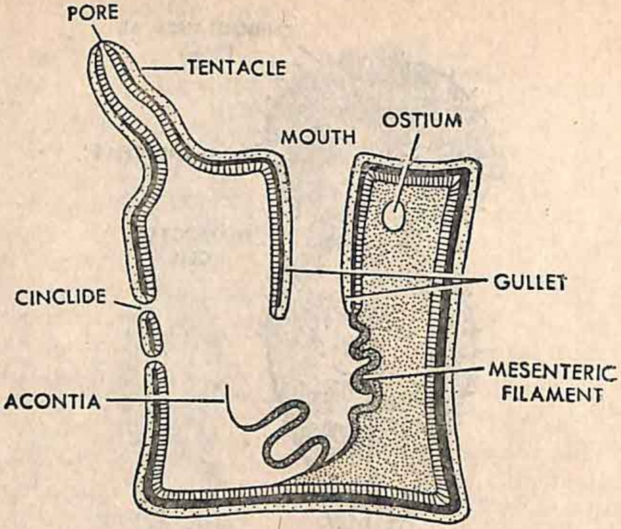


Fig. 4.42. Diagramatic V. S. of a sea-anemone

Histology of Acontia—The acontia are pyriform in cross section. They consist of mesogleal core covered by a columnar epithelium which on the broad surface is packed with long nematocysts. Gland cells, as well as longitudinal muscle fibres and a nerve net are also present (Fig. 4.43).

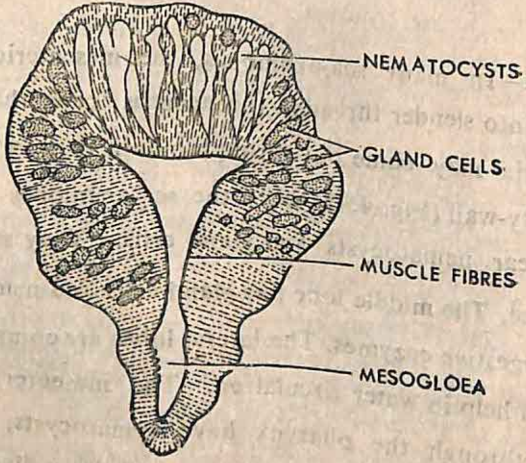


Fig. 4.43. C. S. of an acontium of a sea-anemone

4.48. Movements and Musculature

The animal shows various kinds of contractile movements which are as follows :

(i) Column may be expanded or retracted.

(ii) Tentacles extend to a considerable length or may be completely retracted back and become hidden by the upper end of the column which becomes folded over them.

(iii) Gullet and septa may be partially everted through the mouth, and

(iv) Creeping movement of the base and therefore the muscles are well developed.

There are five sets of muscles :

(i) Longitudinal muscle or the retractor muscles,
(ii) Parietal muscles,
(iii) Transverse muscles,
(iv) Sphincter muscles,
(v) Basilar muscles.

(i) Longitudinal Muscles—They lie over the surface of the septa running from base to disc. When they contract they shorten the mesenteries and draw the disc towards the base, thus retracting the tentacles. They form thick buldging on the surface side of septa.

(ii) Parietal Muscles—They run obliquely across the lower and outer angles of the mesentery. They approximate the column to the base and cause thickening on the surface side of the septa and are quite prominent.

(iii) Transverse Muscles—They run across the longitudinal muscles and at right angles to them but are not very prominent. They produce narrowing of the septa.

(iv) Sphincter or Circular Muscles—They are present encircling the body at the junction of the column and the oral disc.

(v) Basilar Muscles—They lie at the base of the body of anemone and cause the contraction and expansion of the pedal disc.

Tentacles are also capable of independent movement since they also contain both longitudinal and transverse muscles.

4.49. Histology of the Body-Wall (Fig 4.44)

The body-wall is made up of (i) outer ectoderm, (ii) inner endoderm and (iii) mesoglea which is tough and thick. The gullet is lined with ectoderm and the face facing the intermesenteric chambers has endodermal lining. Mesenteries consist of a supporting plate of mesoglea covered on both sides by endoderm.

Histology—Histology is better shown by the transverse section of a tentacle as described below :

(i) Ectoderm—It consists of long columnar ciliated epithelial

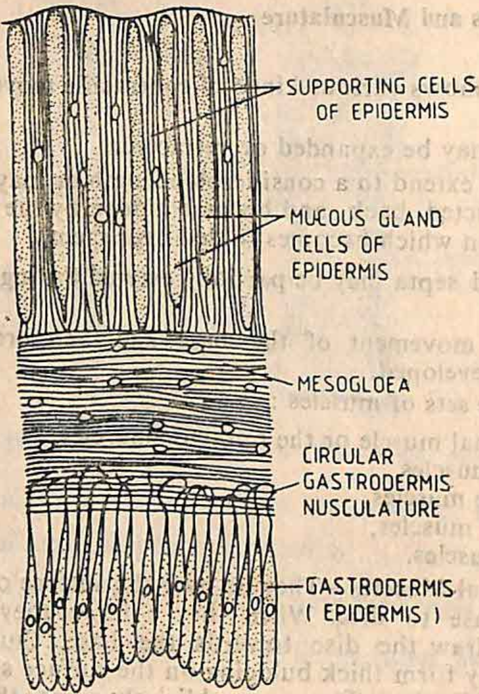

SUPPORTING CELLS OF EPIDERMIS
MUCOUS GLAND CELLS OF EPIDERMIS
MESOGLOEA
CIRCULAR GASTRODERMIS NUSCULATURE
GASTRODERMIS (EPIDERMIS)

Fig. 4.44. *Metridium* : T. S. through the body-wall

cells. Specially on tentacle and oral disc there are also sensory nerve cells, gland cells of mucus type and nematocysts. Sensory nerve cells are numerous on the tentacles and oral disc and on sole as well. They are rare in column. Gland cells are numerous in mesenteric filaments.

(ii) **Mesoglea**—It is in the form of connective tissue having ground matrix with scattered cells. Mesoglea is of three types : (a) gelatinous—here the mesenchyne is composed of gelatinous matrix with amoebocytes; (b) fibrous—here mesoglea has fibrous matrix with scattered amoebocytes. This type of mesoglea is common; (c) Chondroid-like hyaline cartilage

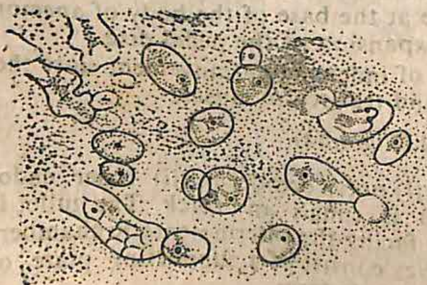


Fig. 4.45. Chondroid type of Mesoglea

—mesoglea has firm colourless matrix with clusters of D-shaped cells and resembles the hyaline cartilage (fig 4.45).

(iii) **Endoderm**—It consists of long columnar flagellated cells, whose bases are drawn into circular muscle fibres. Muscles are partly of spindle shaped nucleated fibres and partly of muscle processes found chiefly into transverse endodermal layer of tentacles. Longitudinal muscles are ectodermal formed of distinct fibres only; muscles of mesentery are endodermal.

4.50. Stinging Clapsules—Nematocysts (Fig. 4.46)

They are found abundantly in mesentric filaments and tentacles. They are of two kinds : (i) spirocyst-found only in tentacles and oral disc, (ii) nematocyst proper—found everywhere, are elongated, slightly curved and are of two sub-types—(a) **basitrichous isorhiza or spirula**. The name spirula was given by **Stephenson** in 1929; (b) **microbasic mastigophores** and **amastigophores** (**bottle brush** type or **penicilli** of Stephenson),

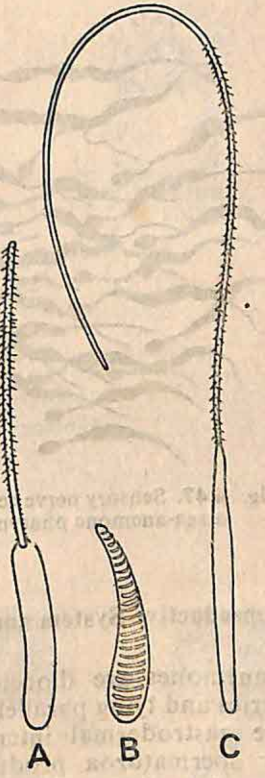


Fig. 4.46. Nematocysts of sea-anemone. A. microbasic amastigophore from the tentacle; B. spirocyst; C. basitrichous isorhiza from acontia

4.51. Digestive System

Sea-anemone feeds on molluscs, crustaceans and other invertebrates and fishes. Prey is paralysed by the nematocysts situated on tentacles and are then carried to the mouth with the help of tentacles. The cilia of tentacles, mouth, and gullet beat and help to force the prey into the gastro-vascular cavity. The food is digested here by enzymes secreted by the secretory cells of the mesenteric filaments. Digested food is absorbed in gastrodermis and undigested residue are thrown out by mouth.

4.52. Nervous System and Sense Organs

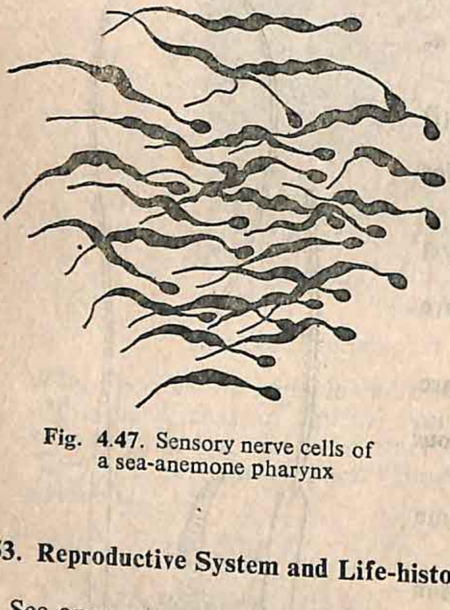


Fig. 4.47. Sensory nerve cells of a sea-anemone pharynx

Nervous system consists of a nerve net in the epidermis of body wall and septa, the two are connected together in mesoglea. These plexis mainly consist of fibre from sensory nerve cells (Fig. 4.47). There are no special localized sense organs.

4.53. Reproductive System and Life-history

Sea-anemones are dioecious. Near the edges of the septa or mesenteries and lying parallel to them, gonads are located. The sex cells are gastrodermal interstitial cells that ripen in the mesoglea. Eggs or spermatozoa produced by gonads are discharged into gastrovascular cavity and finally pass out in sea water through mouth. Fertilizatian takes place in sea water. Zygote develops after undergoing total, unequal or equal cleavage in a **Coeloblastula.** The endoderm is formed by invagination. The embryo elongates into a ciliated **planula** having in some forms an aboral large hard tuft of cilia. At the oral (posterior) pole the blastopore persists in cases of invagination or soon breaks through. Then blastopore becomes the lower opening of stomodaeum. The **planula** larva swims for some time and feeds on micro-organisms. Finally it settles down at the bottom of the sea and attaches itself by aboral end. The tentacles, septa and mesoglea are formed and the planula larva changes into a miniature sea-anemone (fig. 4.48).

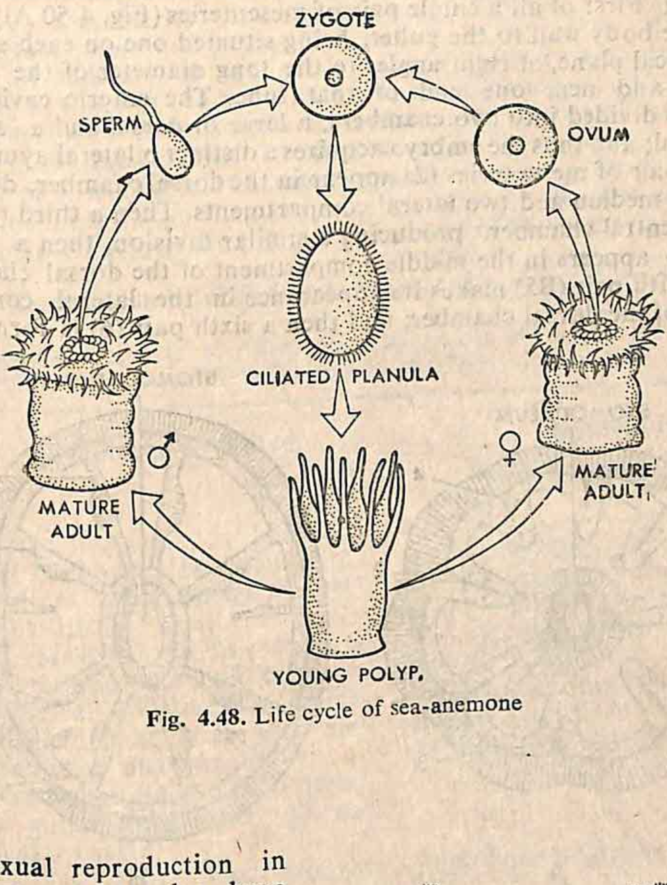


Fig. 4.48. Life cycle of sea-anemone

Asexual reproduction in sea-anemones has also been reported to take place by budding, longitudinal fission, (fig. 4.49) or fragmentation at the edge of the basal disc.

Regeneration—When the animal is cut across the column into two, the lower part regenerates a new oral disc with tentacles but the upper part does not form a new pedal disc but instead it forms a second set of tentacles at its lower aboral surface, thus presenting a case of heteromorphosis.

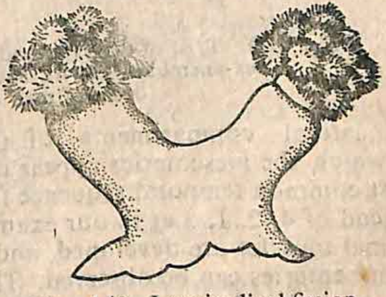


Fig. 4.49. Longitudinal fission of sea-anemone

4.54. Mesentery Formation

The mesenteries are developed in regular order, but in a way, which would certainly not be suspected from their arrangement in the adult. First of all a single pair of mesenteries (Fig. 4.50 A1) grows from the body wall to the gullet, being situated one on each side of the vertical plane, at right angles to the long diameter of the stomodaeum, and near one end of that tube. The enteric cavity thus becomes divided into two chambers, a large or **dorsal** and a smaller or **ventral**; and thus the embryo acquires a distinct bilateral symmetry. Next a pair of mesenteries (2) appear in the dorsal chamber, dividing it into a median and two lateral compartments. Then a third (3) pair in the ventral chamber, producing a similar division, then a fourth pair (4) appears in the middle compartment of the dorsal chamber; then a fifth pair (B5) makes its appearance in the lateral compartments of the dorsal chamber; and then a sixth pair (6) is formed in the lateral compartments of the ventral chamber. The order in which the mesenteries appear differs in different Actinozoa. The most common temporal sequence from dorsal to ventral is 2, 4, 1, 3 instead of 4, 2, 1, 3 as in our example (Fig 4.50A). Soon the longitudinal muscles are developed, and the fate of these primitive pairs of mesenteries can be observed. The third and fourth pairs become the two directive couples of the adult, another couple of primary mesenteries is made, on each side of the vertical plane by one of the mesenteries of the first and one of the sixth pair; a third couple is

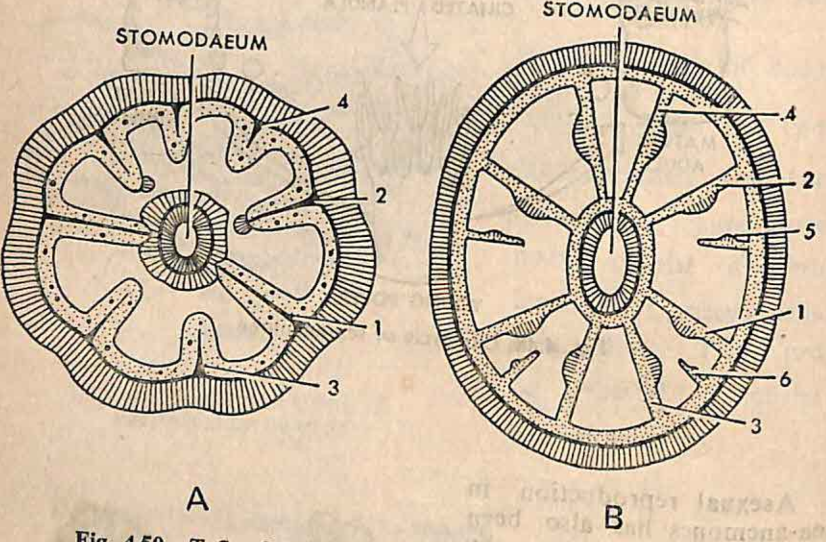


Fig. 4.50. T. S. of early (A) and later (B) stages of an embryo of sea-anemone. The mesenteries are numbered in the order of their development

similarly formed by a mesentery of the second and one of the fifth pair. Thus it is only in the case of the directive mesenteries that an adult couple coincides with an embryonic pair while in other instances the two mesenteries of a couple are of different orders belonging to distinct embryonic pairs. The mesenteric filaments of the first cycle of mesenteries are partly ectodermal and partly endodermal in origin, those of the remainder entirely endodermal. The tentacles are developed in a somewhat similar order to that of the development of the mesenteries. The first to appear is connected with the larger or dorsal enteric chamber mentioned above, for some time it remains much larger than any of its successors, and thus accentuates in a marked degree the bilateral symmetry of the embryo.

4.55. Comparison between Sea-anemone and a Hydroid Polyp

Sea-anemone is a polyp, formed on the same general lines as a hydroid polyp, but differs from it in the following points :

Sea-anemone (Polyp)	**Hydroid Polyp** **(Polyps of *Obelia*)**
1. Body-wall has ectoderm, endoderm and mesoglea between them.	1. Ectoderm, endoderm, and mesoglea present in body wall.
2. Mesoglea has fibrous elastic fibres and amoeboid cells.	2. Mesoglea has no fibrous elements.
3. Oral cone absent, mouth is flushed with oral disc and opens into pharynx, gullet or stomodaeum lined by ectoderm. The gullet opens into gastro-vascular cavity.	3. Mouth lies on oral cone and directly opens into gastro-vascular cavity. No gullet.
4. The gullet has grooves (siphonoglyphs).	4. Siphonoglyphs absent.
5. Endocoels and exocoels (due to the presence of mesenteries) are present.	5. The gastro-vascular cavity is undivided.
6. Mesenteries (primary, secondary, and tertiary) are found between the body-wall and stomodaeum.	6. Mesenteries are absent.
7. Mesenteric filaments are present.	7. Absent.
8. Acontia are present. When the animal contracts the acontia protrude out through mouth or pores (cinclides) on body wall.	8. Acontia and cinclides are absent.

Sea-anemone (Polyp)	Hydroid Polyp (Polyps of *Obelia*)
9. The body is divided into basal or pedal disc, column, and oral disc. The oral disc bears many tentacles in multiple of five in several circles.	9. Such a division of body and arrangement of tentacles are absent.
10. Polyps (sea-anemone) are large in size and bulky. They are solitary.	10. Polyps are small in size and colonial.
11. Polyps have bilateral symmetry underlying their superficial radial symmetry.	11. Polyps have radial symmetry.
12. Polyps do not show polymorphism.	12. Feeding zooids (Hydranths), asexually reproducing zooids (blastostyles which give rise to medusae-sexnal zooids, by budding) are present in the colony. Thus polymorphism is present.
13. Polyp (sea-anemone) does sexual as well as asexal reproduction but never gives rise to a medusa.	13. Polyp (blastostyles) does asexual reproduction and gives rise to medusae.
14. Gonads are endodermal and are present on mesenteries.	14. Gonads are absent in polyps but present in medusa and are ectodermal.
15. There is no alternation of generation except in one doubtful case.	15. Alternation of generations between asexual polypoid phase and sexual medusoid phase present.
16. Muscular system well developed and differentiated into longitudinal retractor, transverse and parietal muscles.	16. Muscles are very poorly developed.
17. Nematocysts are more complex and are found on body wall, oral region, tentacles and stomodaeum.	17. Nematocysts are present on tentacles and are of simple form.
18. Body not covered by perisarc.	18. Body covered by perisarc. Perisarc covering the Hydranths are called Hydrotheca and that covering the Blastostyles, the gonotheca.
19. Some sea-anemones show commensalism with hermit crab.	19. This phenomenon is absent here.

Comparison between sea-anemone and a scyphozoan polyp, Scyphistoma.

4.56. Sea-anemone is a polyp formed on the same general lines as a Scyphistoma, but differs from it in the following points :

Comparison between sea-anemone and Scyphozoan polyp (Hydra tuba or Scyphistoma)

Sea-anemone	Scyphistoma
1. Size of the body is larger and more bulky than the scyphozoan polyp.	1. Body size small.
2. Substance of body firm.	2. Substance of body is not firm.
3. Have numerous tentacles arranged in multiples of five.	3. Such an arrangement of tentacles is absent.
4. An oral cone (manubrium) absent, the mouth being nearly flushed with the surface of the oral disc.	4. An oral cone (manubrium) is present at the tip of which lies the mouth.
5. Body is short, cylindrical having flower-like appearance. Body is divisible into pedal disc, column, and oral disc. These are separated by grooves.	5. Body trumpet-shaped or has bizzare appearance. Body is divided into manubrium, column, and basal disc but they are not separated by grooves.
6. Many mesenteries extend from the body-wall to the gullet either completely or incompletely, are of different sizes and are distinguished into primary, secondary, and tertiary couples.	6. Only four septa all of the same size and placed interradially extend from the body wall into the enteric cavity.
7. The six primary mesenteries are perforated by paired ostia, one is marginal and the other axial.	7. Only one septal ostium is present.
8. Gonads are found on the mesenteries.	8. Gonads are absent.
9. Strobila and ephyra stages are absent.	9. Strobila and ephyra stages are present.
10. Bilateral symmetry underlying superficial radial symmetry.	10. Radial symmetry.

□□□

5. PHYLUM—ACNIDARIA (CTENOPHORA)

5.1. Although known to the ancients since time immemorial, the first definite account with recognizeable figures was given in 1671 by a Ship's doctor **Martins**, in the vicinity of Spitzbergen. **Eschschultz** (1828-33) created the order Ctenophora and 2 other orders. All these three orders were made subdivision of the class Acephals regarded as intermediate between Zoophytes and Echinoderms. **Hatscheck** (1889) regarded Ctenophores as separate group and regarded them a distinct phylum. **Hyman** (1940), **Barnes** (1980) and other authorities in recent years also regard them as separate phylum.

5.2. Definition

The Ctenophora are biradially symmetrical radiata without nematocysts, with a gelatinous ectomesoderm containing mesenchymal muscle fibres and with eight meridonal rows of ciliary plates present through out life or in 2 genera in larva only.

5.3. General Characters

1. They are pelagic Acnidarians without nematocysts in which colony is never formed. The body is transparent with biradial symmetry and oral and sub-oral surfaces.

2. No indication of a polyp stage.

3. Ciliary movement throughout life, cilia have fused to form comb-like structures arranged in eight meridional rows or swimming plates (costae).

4. Tentacles 2 in number when present, tentacles lie in opposite (right and left) peraradii and can be retracted into pouches. Special adhesive cells, the collablasts on tentacles help in food capture.

5. Enteron opens to the outside by a large stomodaeum which acts as the main digestive cavity.

6. A system of canals arise from the enteron, the ultimate branches of these canals are adradial and have a meridional position lying beneath the swimming plate; a single axial canal runs to the aboral pole where it usually opens by excretory pores.

7. Gastric filaments are absent, skeletal system is also absent.

8. A single sense organ situated at aboral pole is present. It is a peculiarly modified lithocyst.

9. Gonads (endodermal in origin) of both sexes are found in the same individual, the ovaries and testes being formed on opposite sides of the meridional canals.

10. The zygote undergoes unequal cleavage, and the gastrula is formed by epiboly or overgrowth which develops ultimately into a **cydippid** larva.

11. There is no alternation of generations.

12. In some cases metamorphosis occurs during development.

5.4. Classification

Phylum—Acnidaria
Class—Ctenophora

The class Ctenophora is divided as follows—

Sub-class—Tentaculata (Micropharyngea)

Order Cydippida—(a) Tentaculata having 2 tentacles which can be retracted into sheaths. (b) Unbranched meridional and stomodaeal vessels present. (c) The body rounded or oval or slightly compressed in the lateral plane.

Ex. *Hormiphora* and *Pleurobranchia.*

Order 2. Cestida—(a) Tentaculata possessing band-like or ribbon-like body due to the extreme compression of the body in the sagittal plane. (b) The bases of the two main reduce tentacles lie in sheathes and there are also many lateral tentacles contained in a groove. (c) Two of the 4 comb rows are reduced. (d) The meridional and stomodaeal vessels have undergone anastomosis.

Ex. *Cestus Veneris*, *Velamen.*

Order 3. Lobata—(a) Tentaculata with numerous lateral non-retractile tentacles lodged in a groove, the bases of the two main reduced tentacles are also present but are without sheaths. (b) Stomodeal and meridional vessels unite with one another. (c) Body is laterally compressed and is produced into two large oral lobes or lappets and into 4 pointed processes.

Ex. *Deiopea*, *Mnemiopsis.*

Order 4. Platyctenea—(a) Tentaculata with greatly flattened body adapted for creeping (b) Possess a pair of retractile lateral sheathed tentacles. (c) The swimming plates (costae) when present are short and deeply situated. The comb plates are present only in larval stage and absent in adult (d) Meridional canals absent, but there is a system of branching peripheral vessels.

Ex. *Ctenoplana*, *Tialfiella*, *Coeloplana*

Sub-Class 2. Nuda (Macropharyngea)

Ctenophora without tentacles.

Order 1. Beroida

(a) Body conical or cylindrical.

(b) Mouth and pharynx are very large. The pharynx or gullet occupies the greater part of the interior of the body.

(c) The meridional vessels are produced into a complicated system of anastomosing branches.

Ex. *Beroe*

5.5. Resemblances between Acnidaria (Ctenophora) and Cnidaria (Coelenterata)

1. Tetramerous symmetry of the body.
2. Absence of coelom.
3. Gelatinous mesoglea between ectoderm and endoderm.
4. Tissue grade of organization.
5. Branching gastro-vascular canals.
6. Diffused nervous plexus.
7. Respiratory, excretory and circulatory systems absent.
8. Endodermal origin of gonads.
9. Statocysts (sense organs) are present.

5.6. Differences between Ctenophora and Cnidaria (Coelenterata)

1. Polymorphism exhibited in Hydroid Cnidarians is lacking in Ctenophores.
2. Hydroid Cnidarians are colonial while Ctenophores are solitary.
3. Alternation of generation is found in the life-history of Cnidarians but is absent in Ctenophores.
4. Nematocysts absent in Ctenophores but present in Cnidaria.
5. Presence of colloblasts on the tentacles of Ctenophores which are absent in Cnidarians. The tentacles of the latter bear nematocysts.
6. Presence of eight ciliated meridional comb plates for locomotion in Ctenophores but absent in Cnidarians.
7. Presence of wide mouth and gullet in Ctenophora.
8. Mesenchymal muscle cells present in Ctenophora.
9. Cleavage is of determinate type in Ctenophora but indeterminate in Cnidarians.
10. A free swimming **Cydippid** larva (resembling closely adults of order cydippida) is found in the life-history of Ctenophores but a free-swimming **planula** larva occurs in Cnidaria.
11. An invaginate gastrula is found in Ctenophora but stereogastrula occurs in Cnidaria.

CTENOPHORA

Hormiphora plumosa

5.7. Classification

Phylum—Acnidaria (Ctenophora)
Class—Tentaculata
Order—Cydippida
Genus—Hormiphora
Example—*Hormiphora plumosa*

5.8. External Features

They are pear-shaped organisms about 5-20 mm in diameter, and look transparent. *Hormiphora plumosa* is found in the Mediterranean, and allied forms belonging to the same genus or to the closely allied genus *Pleurobranchia* are pelagic and of world-wide distribution. From the broad or aboral end, arise two long tentacles provided with numerous tag-like processes and each tentacle springs out from a deep cavity or sheath into which it can be

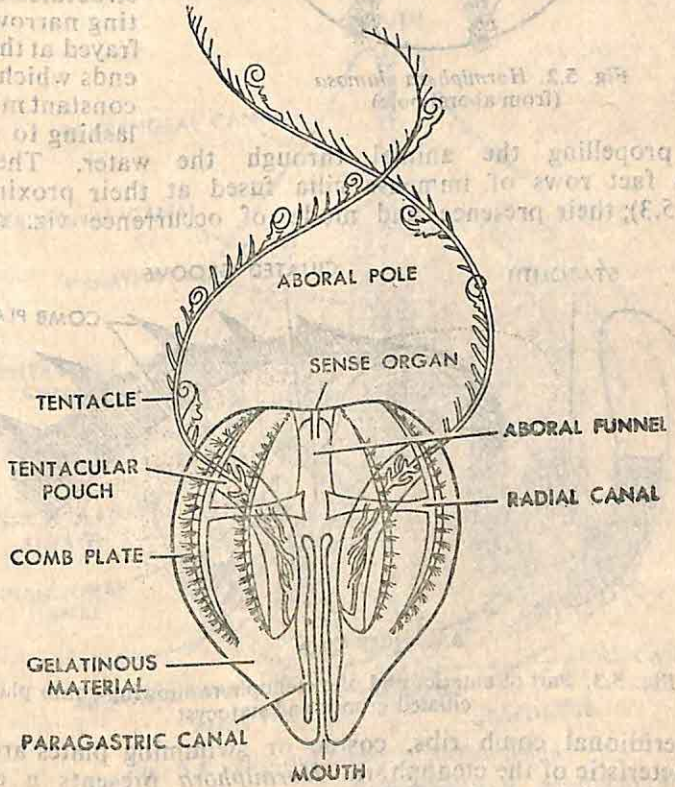


Fig. 5.1. *Hormiphora plumosa* (side view)

completely retracted. At the opposite or aboral pole lies peculiar sense organ in a slight pit.

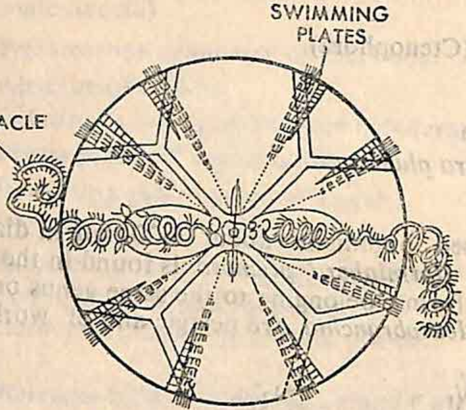


Fig. 5.2. *Hormiphora plumosa* (from aboral pole)

Presence of 8 equidistant meridional bands starting from near the aboral pole and extending about two third of the distance towards the oral pole is noteworthy (figs. 5.1 and 5.2). Each band is constituted by a row of transversely arranged comb-like structures constituting narrow plates frayed at their outer ends which are in constant movement lashing to and fro thus propelling the animal through the water. The combs are in fact rows of immense cilia fused at their proximal ends (Fig. 5.3); their presence and mode of occurrence viz. arranged in meridional comb ribs, costae or swimming plates are strictly characteristic of the ctenophora. *Hormiphora* presents a combination of radial and bilateral symmetry as in some Hydrozoa such as *Ctenaria* and in the majority of Actinozoa. The swimming plates are radially arranged and mark the eight adradii, but the slit-like mouth and the two tentacles indicate a very characteristic bilateral symmetry (fig. 5.3).

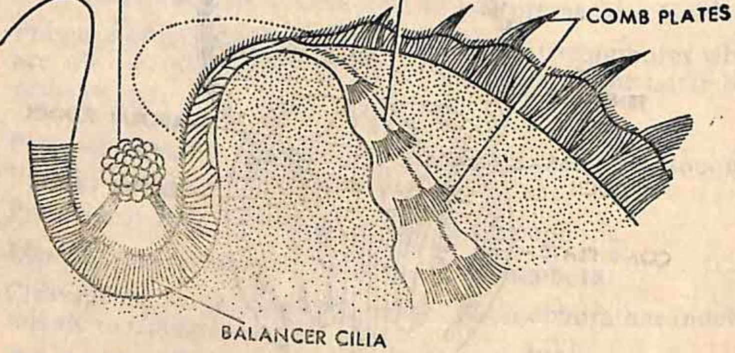


Fig. 5.3. Part of anterior end of a ctenophore showing comb plates, ciliated groove and statocyst

An imaginary line passing from the middle of the mouth to the sense organ is the primary axis. A plane passing through the longitudinal axis of the body, parallel to the long axis of the mouth is called the vertical or sagittal plane, it includes two perradii which are respectively dorsal and ventral. A plane at right angles to this, passing throngh both tentacles, and including right and left per radii is called the transverse or lateral plane. It is along these 2 planes alone that the body is capable of division into approximately two equal halves.

5.9. Enteric System

The **mouth** leads into a flattened tube (fig. 5.4) often called the **stomach** but much more correctly called the gullet or stomodaeum. It reaches about two third of the way towards the aboral pole and its walls are produced internally into ridges to increase the area of absorption. Digestion occurs in stomodaeum which is thus physiologically though not morphologically a stomach. Products of digestion make their way into various parts of canal system and indigestable matters are passed out at mouth. Towards its upper or aboral end the stomodaeum gradually narrows and opens into a cavity, the infundibulum (=stomach of an actinozoan or a medusa)

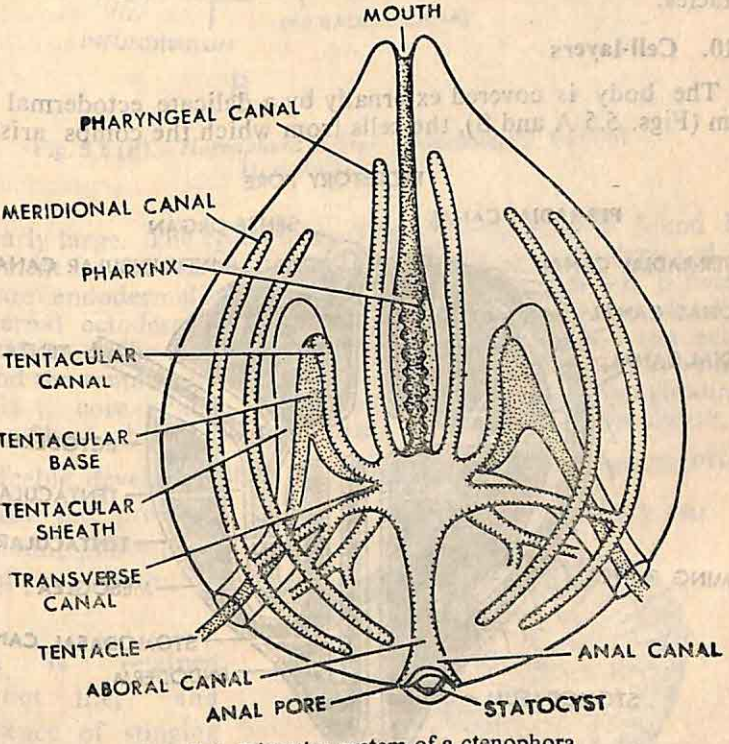


Fig. 5.4. Digestive system of a ctenophora

which is flattened in a direction at right angles to the stomodaeum i. e. in a transverse plane. From the infundibulum three tubes are given off : one, the infundibular canal which passes directly upwards and immediately beneath the aboral pole and divides into four short branches, two of which open on the exterior by minute apertures, the excretory pores. The two other canals given off from the infundibulum are per radial canals which pass directly outwards in the transverse plane and each divides into 2 inter-radial canals which in their turn divide each into 2 ad-radial canals. These successive bifurcations of canal system all take place in a horizontal plane and each of the ad-radial canals opens into a meridional canal which extends upwards and downwards beneath the corresponding swimming plate. Furthermore, each per-radial canal gives off (1) a stomodaeal canal which passes downwards, parallel to and in close contact with stomodaeum and (2) a tentacular canal which extends outwards and downwards into the base of the corresponding entacles.

5.10. Cell-layers

The body is covered externally by a delicate ectodermal epithelium (Figs. 5.5 A and B), the cells from which the combs arise being

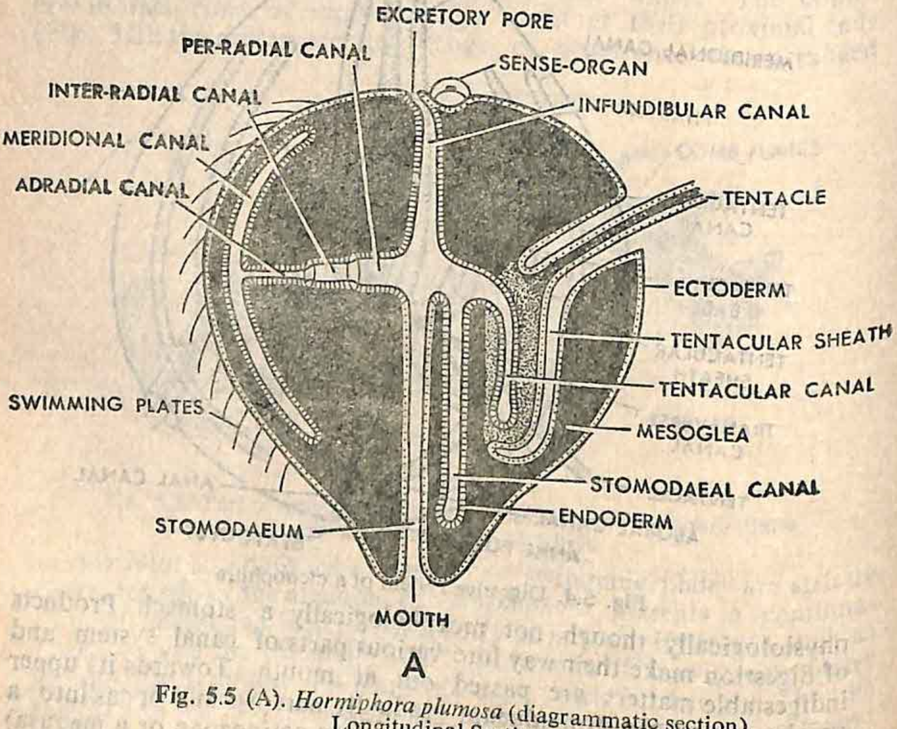


Fig. 5.5 (A). *Hormiphora plumosa* (diagrammatic section)
Longitudinal Section

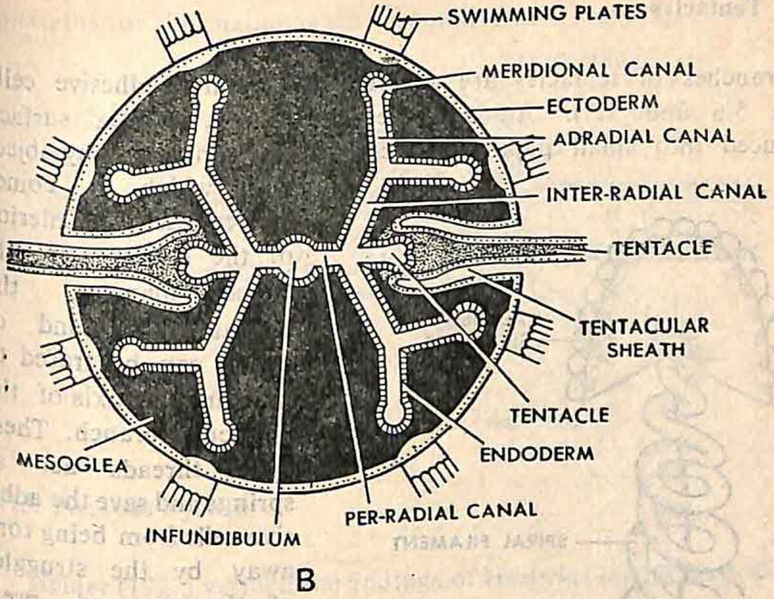


Fig. 5.5 (B). *Hormiphora plumusa* (diagrammatic section) Horizontal Section

particularly large. The epithelium of the stomodaeum is found by development to be ectodermal, that of the infundibulum and its canals are endodermal—both are ciliated. The interval between the external ectoderm and the canal-system is filled by a soft jelly-like mesoglea. The tentacle-sheath is an invagination of the ectoderm and the tentacle itself is covered by a layer of ectoderm within which is a core or axis formed by a strong bundle of longitudinal muscular fibres which serve to contract the tentacle into its sheath.

The feeble development of the muscular system is of course correlated with the presence of swimiming plates-main organs of progression.

Cilia is retained throughout life, and the absence of stinging capsules is a noteworthy feature in the whole Phylum Acnidaria (Ctenophora).

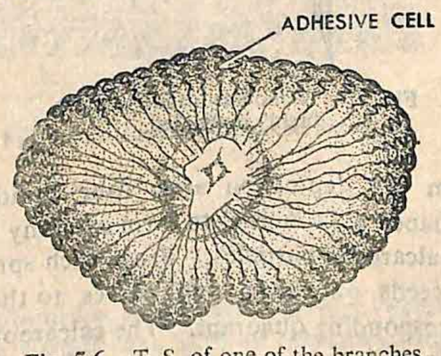


Fig. 5.6. T. S. of one of the branches of a tentacle

5.11. Tentacles

Branches of tentacles are covered by peculiar adhesive cells (Figs. 5.6 and 5.7). An adhesive cell has a convex surface produced into small papillae which readily adhere to any object with which it comes into contact. The interior of the cell is a spirally coiled filament, the delicate inner end of which can be traced to the muscular axis of the tentacular branch. These spiral threads act as springs and save the adhesive cells from being torn away by the struggles of the captured prey. A second straight filament represents the modified nucleus of the cell.

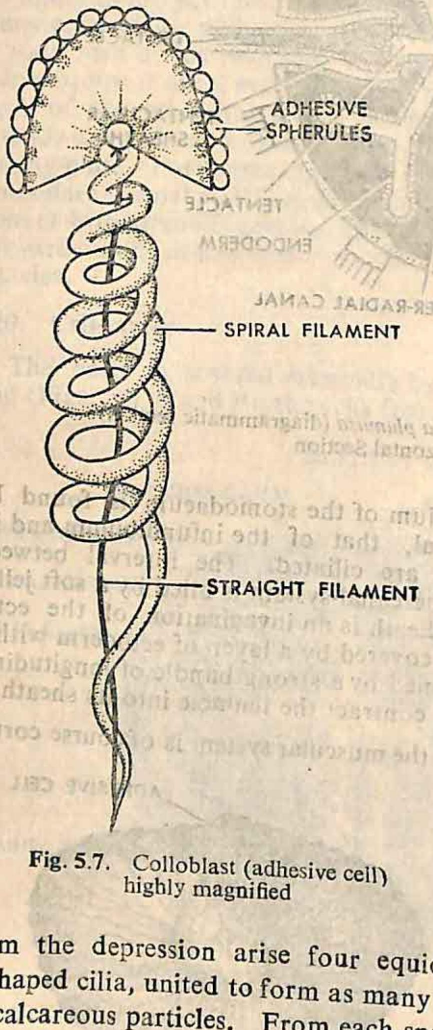


Fig. 5.7. Colloblast (adhesive cell) highly magnified

5.12. Sense Organ

The principal sense organ is a peculiar apparatus situated at the aboral pole. In this region is a shallow depression lined by epithelium and produced in the transverse plane into two narrow ciliated areas, the polar plates; from the depression arise four equidistant groups of very large S-shaped cilia, united to form as many springs which support a mass of calcareous particles. From each spring a pair of ciliated grooves proceeds outwards, and passes to the two swimming plates of the corresponding quadrant. The calcareous mass with its springs, is enclosed in a transparent case or bell, formed of coalesced cilia. It appears that the whole apparatus acts as a kind of steering gear or apparatus for the maintenance of equilibrium (Fig. 5.8).

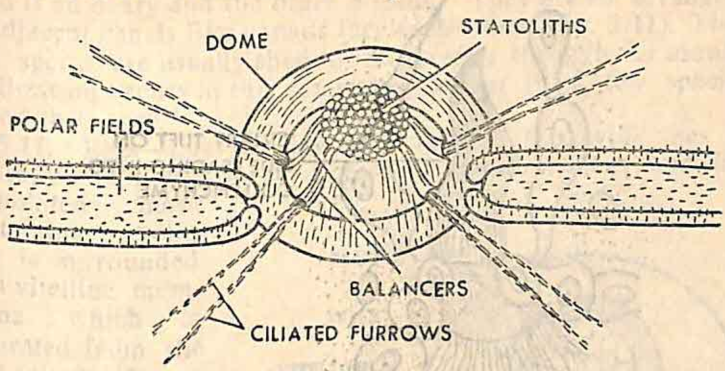


Fig. 5.8. Sense organ (statocyst)

5.13. Nervous System

Heider (1927) verified the findings of **Hertwig** (1880) that a Ctenophora possesses a distinct nervous system of the same type as that of Cnidaria. There is a general sub-epidermal plexus throughout the surface, composed of multipolar ganglia cells and neurites (Fig. 5.9). Nerve elements are also traceable in mesoglea. Thus the nervous system is diffused with no concentration of ganglia and no region of central control.

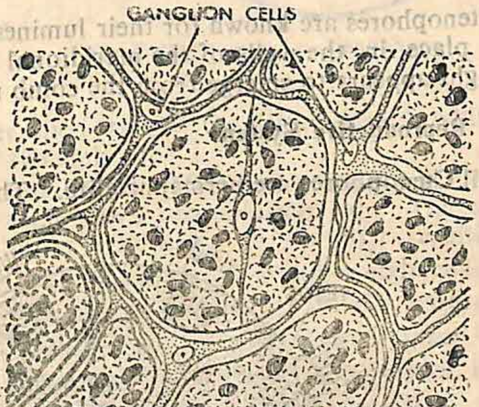


Fig. 5.9. Ganglion cells and nerve net

5.14. Excretory System

It cannot be said with certainty whether there is any excretory system. However, the cell rosette may have an excretory function (Fig. 5.10).

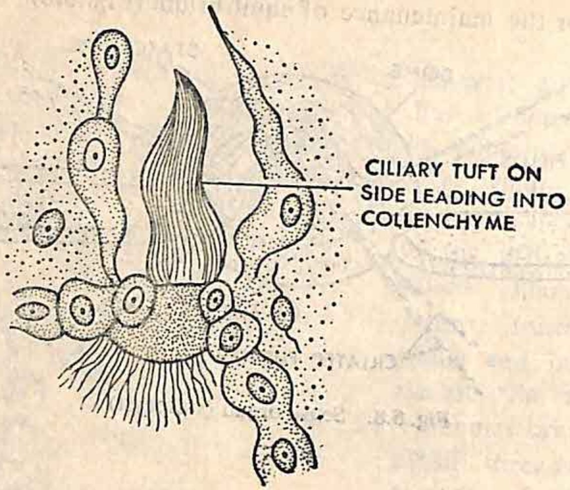


Fig. 5.10. Ciliary tuft

5.15. Luminescence

Ctenophores are known for their luminescence. Light production akes place in the walls of the meridional canals so that externally the light appears to emerge from the comb rows.

5.16. Reproductive System

All Ctenophores are hermaphrodite. The gonads are like two

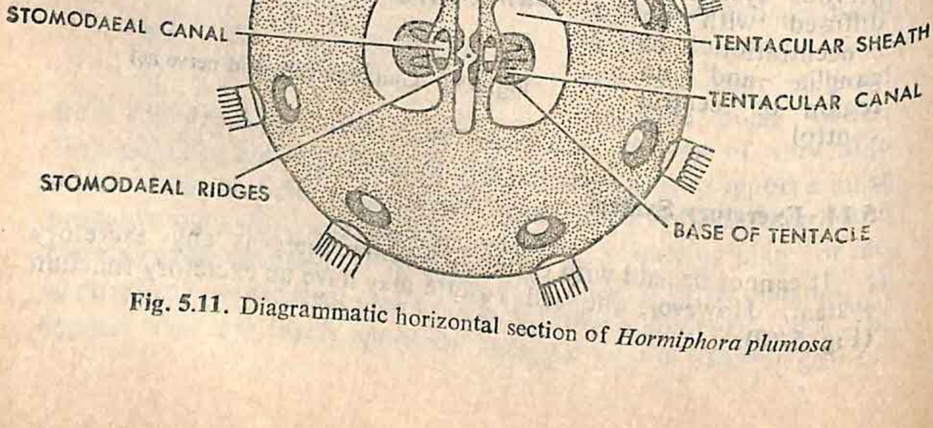


Fig. 5.11. Diagrammatic horizontal section of *Hormiphora plumosa*

bands located in the thickened wall of each meridional canal. One band is an ovary and the other a testis. They are so arranged that in adjacent canals like gonads face each other (Fig. 5.11). The eggs and sperm are usually shed to the exterior through the mouth, and fertilization occurs in the sea-water, except in a few species that brood their eggs.

5.17. **Eggs**—Eggs are first centrolecithal (i.e., yolk lies in the centre) with an outer layer of protoplasm with nucleus and internal vacuolated mass containing yolk. Egg is surrounded by a vitelline membrane which is separated from the protoplasm by a space filled with clear jelly (Fig 5.12).

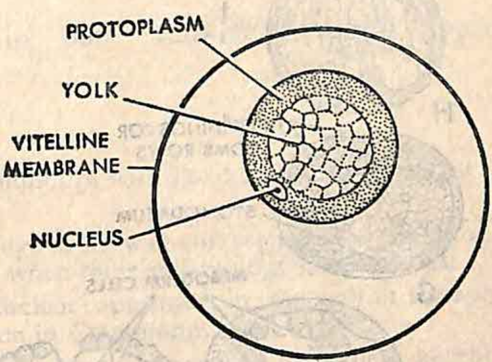


Fig. 5.12. Ovum of a Ctenophora

5.18. **Fertilization** —-Fertilization takes place in sea-water (external). After fertilization the egg becomes telolecithal i.e., protoplasm at one end and yolk at the other, the former is the future dorsal while the latter the ventral end of the embryo.

5.19. **Development** (Fig. 5 13)—The first division is vertical resulting in two cells, each with a protoplasmic cap. The second division is also vertical but at right angle to the first resulting in four cells. Each of these four cells divide to produce eight cells each with a protoplasmic cap. A horizontal division at the base of the protoplasmic cap divides the embryo into eight smaller upper protoplasmic micromeres and eight lower yolky larger macromeres. Finally a solid blastula is formed that is made of a large number of micromeres overlying a smaller number of macromeres. Gastrulation occurs by means of epiboly and invagination. The mesenchyme is derived from the ectoderm like the mesoglea of Cnidarians. The gastrula soon develops into a free-swimming cydippid larva which resembles very closely the adult of Ctenophores that possesses the ovoid or spherical shape. The flattened species of Ctenophores also possess a spherical Cydippid larva which undergoes a more radical transformation to attain the adult shape. The occurrence of spherical larva in Ctenophores gives support to the view that the primitive shape was spherical or ovoid.

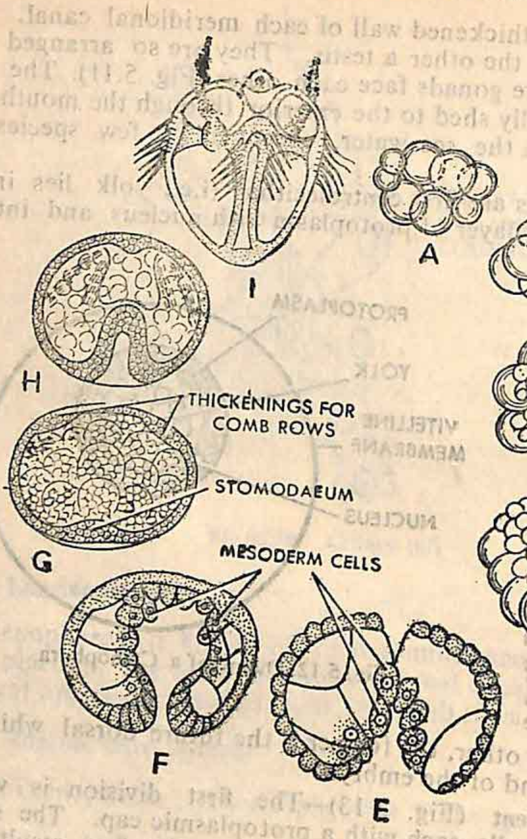


Fig. 5.13. Development of Ctenophore. A. 8 cell stage (from above); B. first set of micromeres formed (side view); C. mass of micromeres (seen from above); D. many micromeres starting to cover macromeres; E. section through embryo undergoing gastrulation, mesoderm cells (so called) are given off from oral ends of macromeres; F. invagination complete, 'mesoderm' in roof of archenteron; G. later stage showing thickenings for comb rows and stomodaeum; H. stomodaeum invaginated, comb rows formed; I. young Cydippid larva.

5.20. Affinities of Ctenophora

Although the Ctenophora are obviously of the same general grade of organization as that of a Cnidaria but it is not possible to derive them from any of the existing group of Cnidaria. An attempt was made to show that the Ctenophora is closer to Porifera than Cnidaria on the following basis :

1. Affinities with Porifera—

Similarity

(i) Simple structure with a large central cavity in which mouth and osculum leads.

(ii) The absence of well developed mesoderm in both the groups.

(iii) Larval stage in both showing some superficial resemblance.

Difference

The affinities of Ctenophora with Porifera is however no more accepted because—

(i) Osculum of sponge in no way corresponds to the mouth o the Ctenophora when their embryology is traced out.

(ii) Presence of inhalent apertures in the wall of the sponges and their absence in Ctenophora.

(iii) Presence of choanocytes in sponges and their absence in Ctenophora.

(iv) Complete absence of spicules in Ctenophora which occur in Porifera.

2. Affinities with Coelenterata (Cnidaria)

(i) Redial and tetramerous symmetry of body.

(ii) Presence of gelatinous mesoglea.

(iii) Absence of coelom and presence of gastrovascular cavity, gastrovascular cavity is branched.

(iv) Presence of tentacles similar to those of medusa.

(v) Nervous system diffused.

(vi) Lack of organ system.

(vii) Endodermal origin of gonads.

(viii) Presence of statocysts (sense organ).

(ix) Tissue grade of organization.

Attempts have been made to relate Ctenophora directly with the Hydrozoa and Anthozoa.

(A) Resemblance with Hydrozoa

An Anthomedusan (Hydrozoa) *Ctenaria* shows remarkable resemblances to a cyddipid Ctenophora such as *Hormiphora*.

(i) Presence of two tentacles in opposite per-radii and each having at its base a deep pouch in the umbrella resembling the tentacle sheath of *Hormiphora*.

(ii) The canals are also very similar. The whole of sub-umbrellar cavity of *Ctenaria* can be compared with the stomodaeum of *Hormiphora*, marginal bell and mouth can be compared with aperture between stomodaeum and infundibulum respectively.

However, these similarities do not seem to indicate any true homology because—

(i) The gullet of Ctenophora is a true stomodaeum developed as an inpushing of oral ectoderm and has therefore a totally different origin from the sub-umbrella of a medusa.

(ii) The tentacles of Ctenaria have no muscular base and they spring from the margin of the umbrella.

(iii) Gonads are developed in the manubrium.

(iv) No trace of aboral sense organ.

Another Hydrozoan, a Narcomedusa of genus *Hydroctena* (Fig. 5.14) presents some resemblances with Ctenophora as follows:

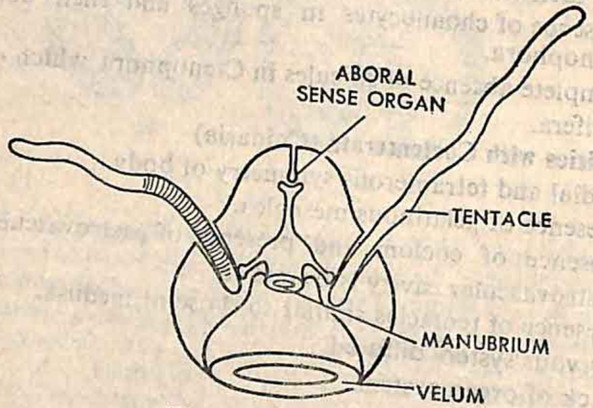


Fig. 5.14. *Hydroctena*

(i) Presence of an aboral sense organ having 2 calcareous bodies supported on springs.

(ii) A canal is given off from the apex of gastric cavity which ends blindly near the sense organ. This canal may be compared with the infundibular canal of *Hormiphora*.

(iii) Two canals on either side ends blindly below the base of tentacle pouch and this may also be compared with the tentacular canal.

(iv) Two tentacles with sheaths are present between both margin and the apex.

However, a close examination of the subject reveals a number of differences between the two. The *Hydroctena* differs from Ctenophora in the following points :

In Hydroctena—

(i) Mesoglea is purely non-cellular.

(ii) Stomodaeum is absent.

(iii) No trace of comb plates is found.

B. Resemblance with Actinozoa (Fig. 5.15)

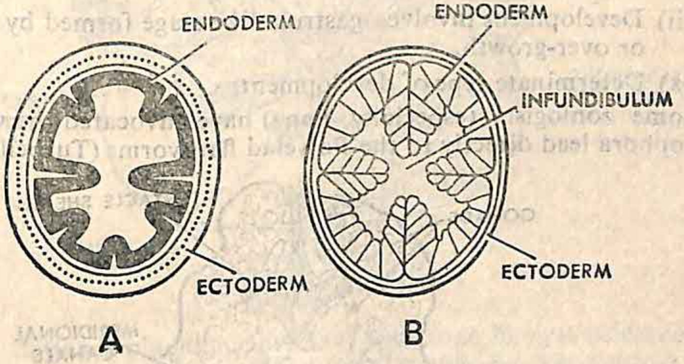


Fig. 5.15. T. S. of embryos of Actinia (A), and Beroe (B)

(i) Presence of stomodaeum.

(ii) Presence of cellular mesoglea.

(iii) Bilateral symmetry of gastrovascular system.

(iv) Four lobed condition of the gastrovascular cavity of the larva.

(v) Gonads are of endodermal in origin.

(vi) Sex cells are discharged into sea-water through mouth.

(vii) Ciliated ectoderm of Actinozoa may be supposed to be the fore-runner of comb-plates.

Points of Difference

(i) No aboral sense organs in Actinozoa.

(ii) No comb-plates in Actinozoa.

(iii) Tentacle solid in Ctenophora and hollow in Actinozoa.

In spite of these similarities the Ctenophores have many special features of their own which are quite different from those of coelenterata (Cnidaria) and it is impossible to determine their affinity with any group of Cnidaria with any degree of certainty and hence Hyman (1940) has kept Ctenophora in a separate phylum of its own.

Special features of Ctenophora :

(i) Oppositely placed tentacles in sheaths.
(ii) Presence of aboral sense organ.
(iii) Absence of Nematocysts and presence of **Lasso** cells.
(iv) Triploblastic because of the presence of well developed ectomesoderm.
(v) Absence of epithelio-muscular cells.
(vi) Eight locomotor meridional ciliated bands or comb-rows.
(vii) Digestive system with aboral anal pores.
(viii) Development involves gastrula-like stage formed by epiboly or over-growth.
(ix) Determinate type of development.

Some zoologists (especially **Lang**) have advocated the view that Ctenophora lead directly to the Polyclad flat-worms (Turbellaria).

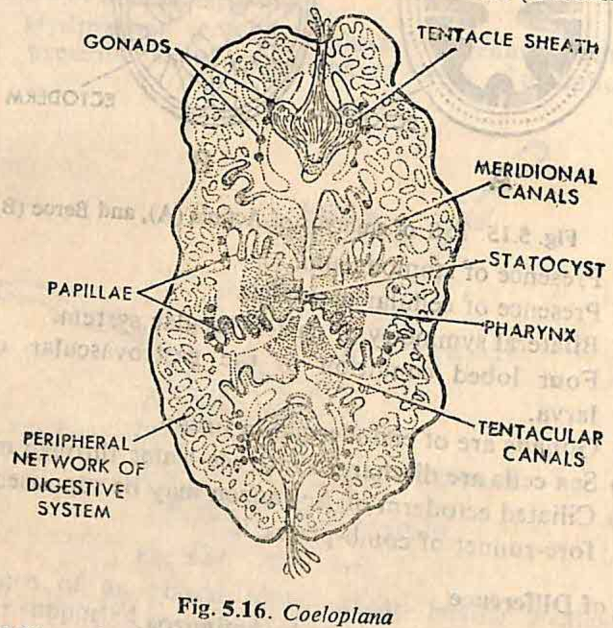


Fig. 5.16. *Coeloplana*

Affinities of Ctenophora with Turbellarians :

Some Platyctenean Ctenophores e.g. *Coeloplana* (Fig. 5.16) and *Ctenoplana* (Fig. 5.17) resemble polyclad turbellarians in the following respects :

(i) Dorsoventrally flattened body and creeping mode of life.
(ii) Central mouth, and branching diverticula of the gut.
(iii) Absence of anus.
(iv) Ciliation of ectoderm.

(v) Mesenchyme with muscle fibres and cells.

(vi) Determinate type of development.

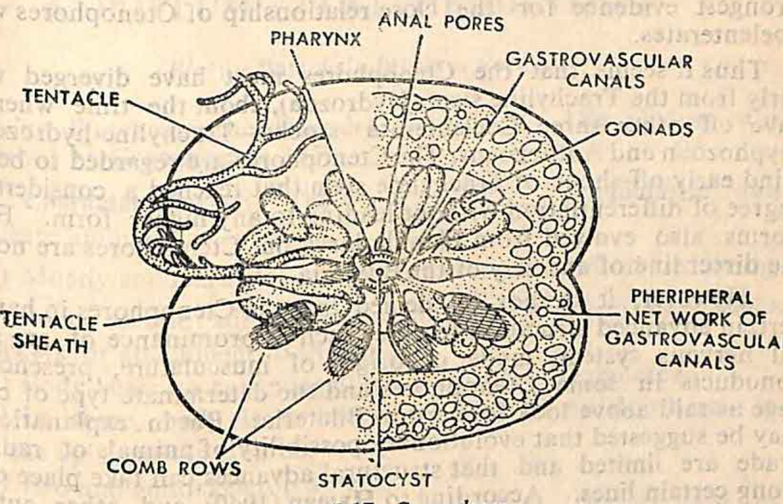


Fig. 5.17. *Ctenoplana*

The flattened platycteneans have therefore, been considered to be missing link between Ctenophora and Turbellaria (flat-worms). But a closer examination reveals that the *Coeloplana* and *Ctenoplana* are typical Ctenophores highly modified for creeping mode of life. Again, among Turbellaria, Acoela and not the Polyclad are more primitive and the *Platyctenea* resemble the Polyclad are more primitive and the Platyctenea resemble the Polyclad and not the Acoela. Therefore, the suggested line of descent i.e.

Ctenophora——→Platyctenea——→Polyclad

becomes untenable.

The assumption, therefore, that the Ctenophore-like organism was the ancestor of flatworm is not convincing (**L. H. Hyman, 1940**).

The Ctenophores present certain advanced structural features which appear to look forward towards the bilateria (Turbellaria). The chief of them are :

(i) Prominance of apical nervous system.

(ii) Mode of origin of musculature.

(iii) Presence of gonoducts in some Ctenophores.

(iv) Determinate type of cleavage.

Some authorities have attached significance to the presence of nematocysts in one of the Ctenophores, *Echlorarubra*. However, recent investigations by **Hadzi** (1959) have shown that the nematocysts belong to Narcomedusae on which it feeds. The nematocysts are not digested but are transferred to the tentacles.

One of the Ctenophores, *Gustrod* which is parasite in the body of *Salpa* has planula larva in its life-cycle, found nowhere else among Ctenophores is supposed by some zoologists to provide strongest evidence for the close relationship of Ctenophores with Coelenterates.

Thus it seems that the Ctenophores must have diverged very early from the Trachyline stem (Hydrozoa), about the time when it gave off other three Coelenterate stocks—Trachyline-hydrozoan, Scyphozoan and Anthozoans. The Ctenophores are regarded to be the blind early off-shoot of Trachyline stem that reached a considerable degree of differentiation without leading to any higher form. Flat-worms also evolved from Planula larva but Ctenophores are not in the direct line of ancestry of the Bilateria.

However, it cannot be denied that the Ctenophores in having certain advanced structural features such as prominance of an apical nervous system, mode of origin of musculature, presence of gonoducts in some Ctenophores and the determinate type of cleavage as said above look forward to Bilateria. But in explanation it may be suggested that evolutionary possibility of animals of radiata grade are limited and that structural advances can take place only along certain lines. According to **Hyman** (1940) and other authorities probably the most important next line of advance is the development of a mesoderm and tendency along this line is seen along all higher groups of radiata.

Undoubtedly the Ctenophores appear to indicate, as **Hyman** (1940) opines, along what lines structural complications will proceed in the next grade (organ system grade of construction) without being themselves involved directly in the line of ancestry of this grade. They are the most differentiated radiates and the stock from which they came differentiating along another direction (bilaterally and antero-posterior axiation) gave rise to bilateria.

* * *

6. PHYLUM : PLATYHELMINTHES

(*Platy*=**flat**; *helminthes*=**worms**)

Phylum Platyhelminthes includes flat-worms. The phylum was established by **Gegenbaur** in 1859.

6.1. **Characteristics**—(i) These are flat, **triploblastic** and **acoelomate** animals.

(ii) Mostly endoparasites but few are ectoparasites or free-living.

(iii) Some secrete adhesive substance, while others have **hooks** and **suckers** for attachment to the host.

(iv) Body bears no appendages and is not truly segmented.

(v) In some, body is covered by a layer of **cuticle** whereas in others the epidermis is ciliated.

(vi) Exo-and endoskeleton absent.

(vii) Incomplete digestive system, sometimes without anus or altogether absent.

(viii) Respiratory and circulatory organs are absent.

(ix) Excretory system consists of longitudinal ducts associated with **flame cells.**

(x) Nervous system is primitive and poorly developed.

(xi) Reproductive organs are well developed.

(xii) They are mostly hermaphrodite with few exceptions.

(xiii) Asexual reproduction in some by transverse fission.

(xiv) Fertilization is generally internal; development is either direct or by the formation of several larval stages.

6.2. **Classification**—The phylum is divided into three classes—turbellaria, trematoda and cestoidea.

Class 1. Turbellaria—(i) Mostly free-living, some are ectoparasites.

(ii) The body is flat, broad and leaf-like.

(iii) The body is unsegmented and epidermis with cilia, mucous cells are rod-like **rhabdites.**

(iv) The intestine is simple sac-like or absent.

(v) Genital opening on ventral surface behind mouth.

Order 1. Acoela—(i) Marine delicate animals.

(ii) Antenior mouth with simple pharynx or absent.

(iii) Flame cells, gonads and gonoducts absent.

Ex. *Convoluta*.

Order 2. Rhabdocoela—(i) Fresh-water or marine, small animals.

(ii) Some are parasites.

(iii) Straight, unbranched digestive tract.

(iv) Some have gonad.

Ex. *Microstomum*.

Order 3. Tricladida—(i) Fresh-water, terrestrial or marine.

(ii) Intestine with an anterior and two posterior branches.

(iii) Two ovaries and many testes.

Ex. *Bipalium*.

Order 4. Polycladida—(i) Large flat leaf-like body; they are exclusively marine.

(ii) Intestine with many branches.

(iii) Eyes and nerve cords are present.

(iv) There are numerous ovaries and testes.

(v) Genital apertures separate.

Ex. *Notoplana*.

Order 5. Allocoela—(i) Mostly marine, few are fresh-water.

(ii) Cylindrical body with straight or branched intestine, bulb-like pharynx.

(iii) 3-4 pairs of longitudinal nerves.

Ex. *Hydrolimax*.

Class 2. Trematoda—(i) These are ecto- or endoparasites.

(ii) Epidermis without cilia and rhabdites.

(iii) Unsegmented flat body is covered by cuticle.

(iv) Suckers are present for attachment to the host.

(v) Branched alimentary canal, anus absent.

(vi) Excretory, nervous and reproductive systems well developed.

(vii) Sense organs are not developed.

(viii) Single ovary; male and female genital pores are separate.

(ix) Simple or development includes many larval forms.

Order 1. Monogena—(i) Ectoparasites of fishes or cold-blooded animals.

(ii) Monogenetic—requires one host to complete life-cycle.

(iii) The oral sucker lacking or poorly developed.

(iv) At the posterior end is a disc-shaped structure called **opisthapter** with spines.

(v) Separate male and female genital apertures.

Ex. *Gyrodactylus*.

Order 2. Digena—(ii) Endoparasite requiring two hosts to complete life-cycle.

(ii) Two suckers without hooks.

(iii) One excretory pore at the posterior end and one genital pore for both male and female genital organs.

(iv) Uterus long with numerous eggs.

(v) Life-cycle includes many larval forms which can reproduce asexually.

Ex. *Fasciola, Schistosoma.*

Order 3. Aspidobothrea—(i) Endoparasites of gut of fishes and reptiles.

(ii) Oral sucker absent, ventral sucker without hooks.

(iii) One excretory pore.

(iv) Only one testis is present.

Ex. *Aspidogaster.*

Class 3. Cestoidea—(i) These are endoparasitic 'tapeworms'.

(ii) The body has a scolex (head) with suckers and hooks, neck and long segmented body. The segment is called proglottid.

(iii) Body covered by cuticle.

(iv) Alimentary canal absent.

(v) Each segment with one set of reproductive organs but in many each segment has both male and female genital organs.

(vi) The larva with hooks, it develops into bladder worm stage called **cysticercus.**

Sub-class 1. Cestodaria—(i) Body is formed by one segment and without a scolex.

(ii) No alimentary canal.

(iii) Single set of reproductive organs.

(iv) Larva with **ten hooks.**

Order 1. Amphilinidea—(i) Endoparasites of coelom of fishes.

(ii) Suckers are absent.

(iii) The male and female genital openings at posterior end of the body.

(iv) The uterus is coiled.

Ex. *Amphilina.*

Order 2. Gyrocotylidea—(i) Eversible proboscis at anterior end.

(ii) Male and female pores are situated at the anterior half of the body.

(iii) Uterus not coiled.

Ex. *Gyrocotylus.*

Sub-Class 2. Cestoda—(i) Elongated, flat body is divided into many proglottids.

(ii) Body is divisible into scolex, neck and strobila.

(iii) Scolex with suckers, spines and hooks for attachment to host.

(iv) Each proglottid with male and female reproductive organs.

(v) Larva with **six hooks.**

Order 1. Tetraphyllidea—(i) Endoparasites of intestine of elasmobranch fishes.

(ii) Scolex with four bothrida.

(iii) Suckers may or may not be present.

(iv) Testes are in front of ovaries.

Ex. *Phyllobothrium.*

Order 2. Diphyllidea—(i) Scolex with 2 bothria.

(ii) These are also parasites of elasmobranches.

(iii) Body has not more than 20 segments.

Ex. *Echinobothrium.*

Order 3. Tetrarhynchidea—(i) Endoparasites (intestine) of fishes.

(ii) Segmented tape-worms with 4 bothria and 4 protrusible proboscides.

(iii) Many testes and bilobed ovary.

Ex. *Tetrarhynchus.*

Order 4. Pseudophyllidea (Bothriocephaloidea)—(i) Endoparasites of vertebrates.

(ii) Six suckers with hookless bothrio are present on scolex.

(iii) Proglottids present or absent.

Ex. *Dibothriocephalus.*

Order 5. Cyclophyllidea—(i) Endoparasites of warm-blooded animals and are with 4 suckers and retractile rostellum.

(ii) Suckers with hooks for attachment to intestine of host.

(iii) Genital pores on one or both the sides.

(iv) Many lobed ovaries.

Ex. *Taenia, Echinococcus.*

PLANARIA

(Free-living Platyhelminthes)

6.3. The earliest bilaterally symmetrical metazoan include the animals belonging to phylum **Platyhelminthes.** Of the three major classes of this phylum. **Turbellaria** includes free-living flat-worms which are inhabitants of fresh-water or wet land covered with plenty of moist vegetation.

The word planaria is a common connotation for a variety of genera of small fresh-water and land turbellaria with an alimentary composed of three main major branches (—**Tricladida**). The common genera of fresh-water planaria include *Dugesia*, *Polycelis*, *Dendrocoelum* and *Procerodes*. Land planarians include *Bipalium* and *Geoplana*. The planarians are the most primitive acoelomate bilateral animals.

6.4. The systematic position of planaria is—

Phylum—Platyhelminthes
Class—Turbellaria
Order—Tricladida
Genera—*Dugesia, Polycelis, Dendrocoelum.*

6.5. Habit and Habitat—Planarians are fresh-water triclads commonly found at the bottom of fresh-water ponds almost throughout the world. The common planaria, *Dugesia* lives in lakes, ponds, streams. Some species have become terrestrial land planarians. These are confined to very humid areas and shelter themselves below logs and moist vegetation.

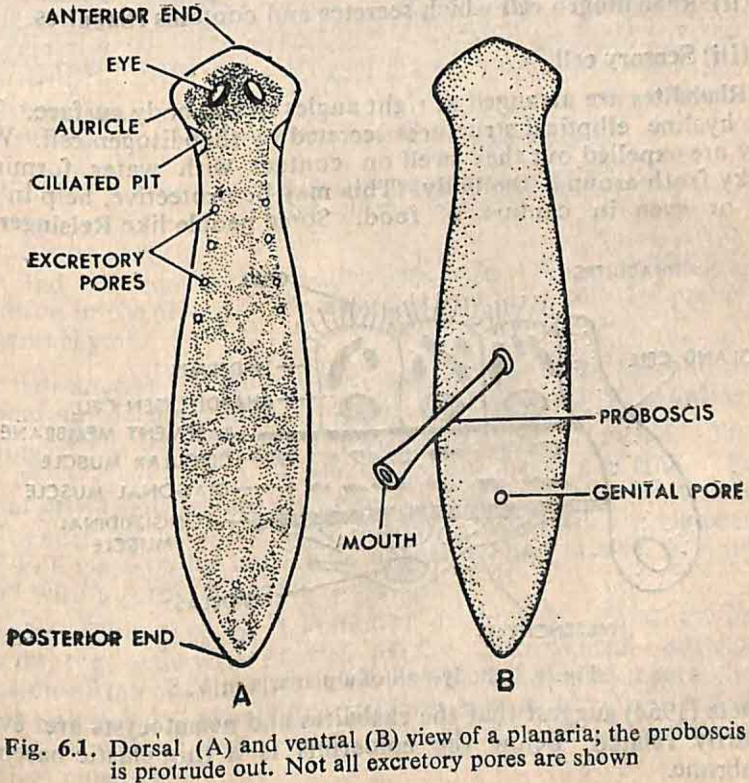


Fig. 6.1. Dorsal (A) and ventral (B) view of a planaria; the proboscis is protrude out. Not all excretory pores are shown

Bipalium is a common land planarian found in India. Planarians are active after dark and avoid strong light.

6.6. External Structure—Planarians are small, flattened thin worms a few mm long. They are bilaterally symmetrical with distinct dorsal and ventral surfaces and right and left borders. There is a distinct broad anterior end and a pointed or tapering posterior end. The lateral projections of the head are called **auricles.** Near the anterior end two rounded black spots or eyes are present. **Polycelis** has many eyes along the anterolateral margin of the body. The dorsal surface is usually coloured with patches of grey, brown or black. On the ventral surface, which is usually pale coloured, about one-third from the posterior tip is the opening of **mouth.** Behind the mouth in the middle line is the **genital pore.** Minute **excretory pores** open out laterally on dorsal side of the body.

6.7. Body-wall—The body of a planarian is covered by a ciliated epidermis. The epidermal cell on its free surface also show a number of microvilli. Cilia are more prominent on the ventral surface. The epidermal cells rest on a basement membrane. Among the epidermal cells the following other types of cell are also present—

(i) **Gland cell** secreting adhesive substances.

(ii) **Rhabditogen cell** which secretes and contains **rhabdites.**

(iii) **Sensory cell.**

Rhabdites are arranged at right angles to the body surface. They are hyaline elliptical structures secreted by rhabditogen cell. When they are expelled out they swell on contact with water forming a sticky froth around the body. This may be protective, help in gliding or even in capture of food. Some people like **Reisinger** and **Kelbetz** (1964) suggest that the **rhabdites** and **nematocysts** are evolutionarily related. Below the epidermis is a thin elastic basement membrane.

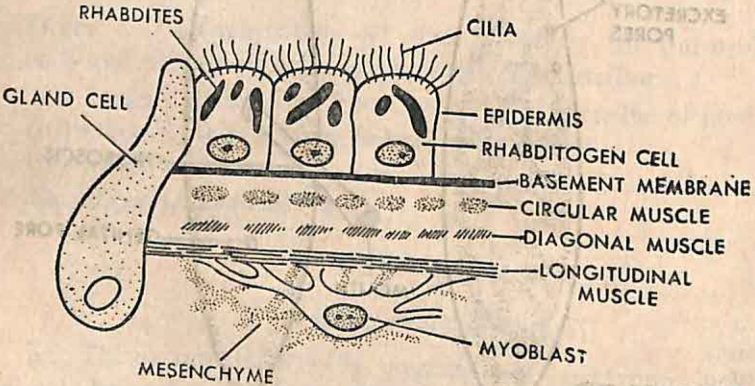


Fig. 6.2. Body-wall of a planaria in V. S.

Pigment is distributed in the body-wall below the basement membrane. Internal to this membrane are **circular, diagonal** and **longitudinal muscles**. The dorsal and ventral body-wall is held together by **dorsoventral muscles**. The longitudinal muscle layer is better developed on the ventral surface as this surface is important in the locomotion of the animal. Below the longitudinal muscle is the **parenchyma** which forms the solid core of the body. Parenchyma is a loose network of irregularly shaped cells of mesodermal origin. A part of the mesenchyme is syncytial. A number of undifferentiated formative cells lie scattered in the parenchyma. The ymultiply by mitosis and differentiate into other type cells. These cells help in regeneration in the planaria. Some gland cells may also be present in the parenchyma.

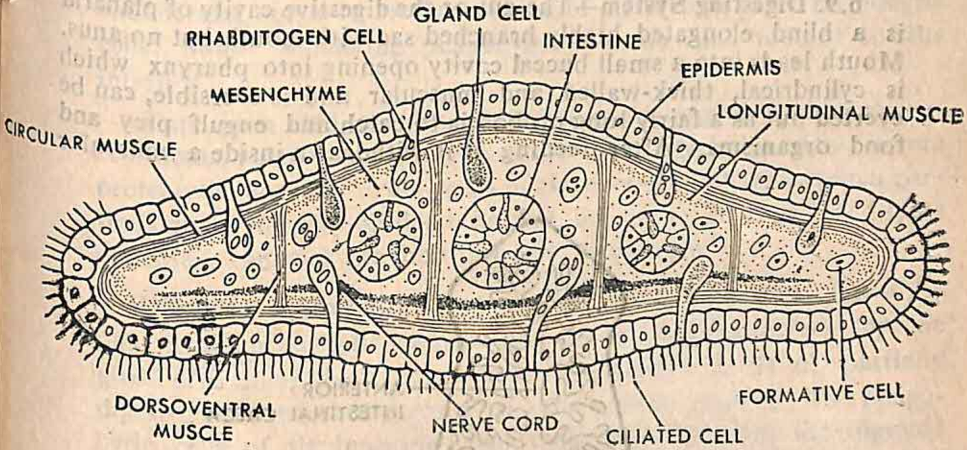


Fig. 6.3. T. S. body of planaria showing the disposition of muscles, nerve cord etc.

6.8. Locomotion—Minute turbellaria can swim near the bottom but planarians do not. They move by (1) **Gliding** and (2) **Crawling.**

Gliding—The anterior end is forward and slightly raised. The motive force is provided by the backward beating of cilia. The epidermal gland cells secrete plenty of slime and the animal simply glides forward on a slimy tract. Gliding locomotion in planaria watched in a glass-walled aquarium appear quite smooth without jerks and with a constant speed.

Crawling—This type of locomotion is brought about by the muscles in the body-wall as well as the dorsoventral muscle. Contraction of the circular and dorsoventral muscles elongate the body, the anterior end is held fixed to the substratum by mucus and the posterior end is then pulled forwards by the contraction of longitudinal muscles.

Sometimes transverse waves of contraction sweep the length of the body causing its undulations in the vertical plane and enabling the planaria to crawl forward. Differential action of local muscle groups produces turning or twisting movements.

A better developed nervous system, sensory structures scattered in the epidermis specially in the anterior region or head, the complexity of muscles, cilia and mucus secretion make a greater variety of movements possible in planaria.

6.9. Digesting System—The gut or the digestive cavity of planaria is a blind elongated highly branched sac with mouth but no anus. Mouth leads into a small buccal cavity opening into pharynx which is cylindrical, thick-walled and muscular and is eversible, can be everted out as a fairly long proboscis to catch and engulf prey and food organisms. After feeding it is withdrawn inside a muscular

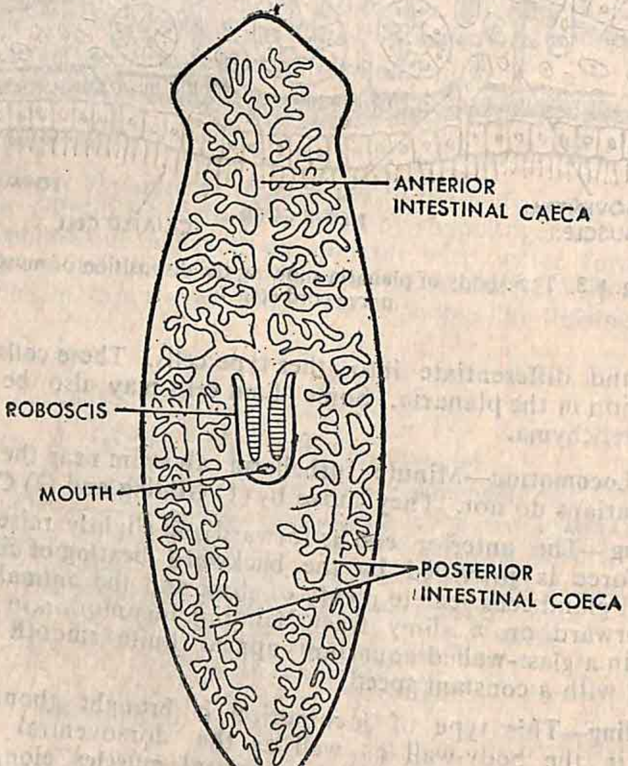


Fig. 6.4. The highly branched alimentary canal of planaria. The ultimate blind caecal branches reach almost every part of the mesenchyme

sheath and the food is passed to the intestine into which the pharynx opens. The intestine immediately divides into three branches (hence the name **Tricladida**). One branch runs forward along the median line, the two other run backward on either side of the median line. Each of these three main branches give off numerous lateral ramifying branches which extend into all parts of the parenchyma. The terminal branches end blindly.

Pharynx is lined with ectodermal cells. The intestinal lining is endodermal, single-layered consisting of gland cells and phagocytic cells. Some wandering phagocytic cells are also present in the intestine.

Planarians feed on dead or alive micro-organisms like micro-crustaceas, small worms, larvae, rotifers etc. Land planarians secrete proteolytic enzymes from cells of the eversible pharynx which partially digest the prey or dead animal before it is engulfed. Some planarians can suck the food through the pharynx.

Digestion is initially extracellular. Food is broken down by pharyngeal proteolytic enzymes and endopeptidases secreted by the gland cells lining the intestinal wall. The broken pieces of partially digested food are then digested by intracellular method. The phagocytic cells of the intestine engulf these particles which are digested by intracellular endopeptidases inside cytoplasmic vacuoles in acidic medium. After about 8 hours the vacuolar content becomes alkaline and digestion in this medium is completed by exopeptidases, lipases and carbohydrases. Undigested food residue is removed through the mouth.

6.10. Excretory System—Removal of nitrogenous wastes is carried out by two pairs of longitudinal trunks of **excretory duct** running along the margin of the body. The two trunks are highly coiled and interconnected by 2-3 transverse cross connections. The excretory ducts open outside by a number of small openings on the dorsal surface. Numerous branches are given off from the ducts, each branch dividing into many fine capillary vessel each being capped with a **flame cell**. Consequently a large number of flame cells are present dispersed within the parenchyma.

A flame cell is a large cell with many cytoplasmic processes at its free end. The nucleus is displaced to one side and the cytoplasm is hollowed out to form a large central cavity which is continuous with the cavity of the capillary vessel. A tuft of flagella hang down

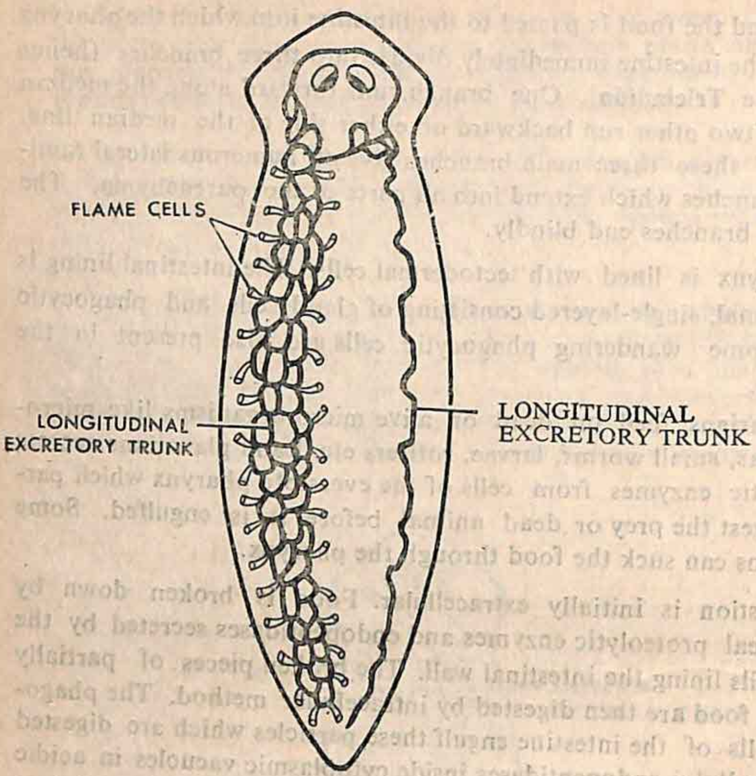


Fig. 6.5. The excretory system of planaria. The branches are shown on the left; on the right only the main longitudina l excretory trunk is shown

into the hollow of the cell. The undulations in these flagella resemble a flickering flame and hence these cells are named **flame cell.** Such an excretory system is called **protonephridial.**

Fluid waste diffuses from the parenchyma into the flame cells and the fluid is pushed towards the excretory pore by the beating of flagella.

The protonephridial system is better developed in freshwater planaria and many zoologists including **Prusch** (1976) believe that the excretory system in *Dugesia* is largely osmoregulatory baling out excess of water and selectively absorbing K^+ and Cl^-. Most of the nitrogenous waste (NH_3) is removed by diffusion from the body surface which has a very large area.

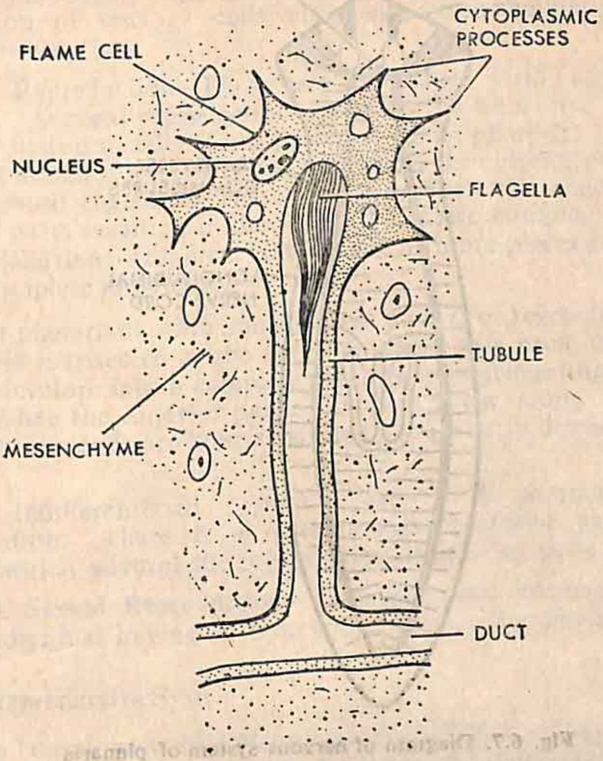


Fig. 6·6. Flame cell of planaria. The tubule is now thought to be part of another cells—conducting cells

6.11. Nervous System--Planarians have a sub-epithelial nervous plexus with a pair of **longitudinal nerves** running from the head to the posterior end on each side of the body. The two longitudinal nerve cords are interconnected by a number of fine **transverse commissures.** Anteriorly the two nerve cords enlarge and meet medially forming a bilobed **cerebral ganglia** or **brain.** The two longitudinal nerve cord give out numerous fine nerves all along their length.

The nervous system of planaria is a distinct advancement over those of the Cnidarians and Ctenophores but ganglia are found only in the brain.

The sense organs include (i) Eyes and (ii) **Auricular organs.**

Eyes are a pair of rounded dark spots on the dorsal surface of the head. The eye is of pigmented cup type. Inside the cup are many sensory cells. The end of these sensory cells near the pigment cup have microvilli arising like a crown. The planarian eye helps

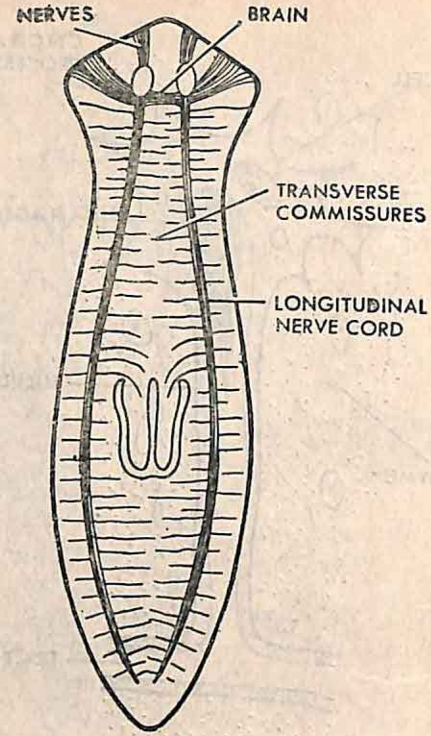


Fig. 6.7. Diagram of nervous system of planaria

in discriminating intensity and direction of light and is not iconogenic or image forming.

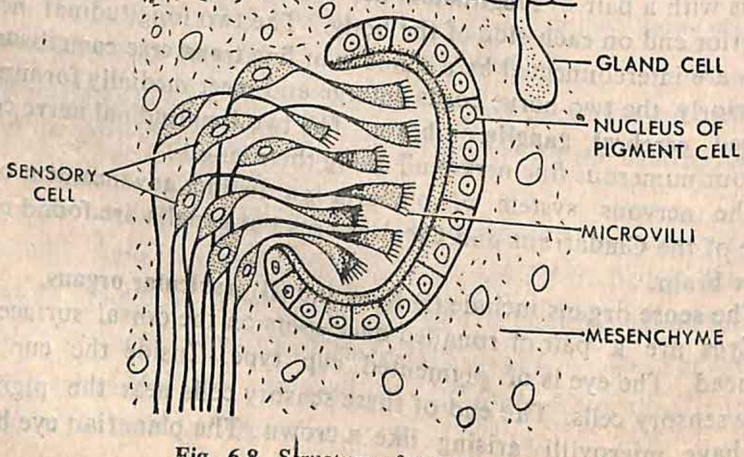


Fig. 6.8. Structure of eye of a planaria

Auricular Organ—The auricular organ located in the head has an aggregation of sensory cells often sunken in shallow pit. It helps in chemo-reception.

6.12. Reproduction—Planarians reproduce both asexually and sexually. **Asexual reproduction** occurs by the transverse fission. The plane of fission usually forms posterior to the pharynx. The posterior part attaches to substratum by mucus, the anterior part stretches forward until the animal snaps into two. Each half regenerates the wanting parts resulting in the formation of two complete planarians. Some planarians fragment into two or more pieces each growing into a complete individual.

Most planarians have considerable powers of regeneration. When a planaria is trisected in the anteroposterior axis each of the three pieces develop into a complete planaria by regenerating the missing parts. When the anterior part of planaria is cut along median line and the cut ends are kept separated the planaria develops a double head.

The indifferentiated formative cells of the parenchyma help in regeneration. There is a distinct **anteroposterior polarity** in the animal which governs the regeneration of missing parts.

6.13. Sexual Reproduction—Planarians are hermaphrodite, the same individual having both male and female reproductive organs.

Male Reproductive System

Two lateral tracts of numerous small spherical **testes** are situated along the margins of the body. A **vas efferens** from each testis joins with adjacent ducts and these open into a longitudinal **vas deferens** situated near the lateral margins of the body. The right and left vas deferens unite in the middle in the posterior part forming a median duct which passes through a protrusible muscular structure of **penis**. The penis opens into a **genital atrium** which opens to the outside ventrally on the midventral line behind mouth. The vas deferens dilates into a **seminal vesicle** before it joins and opens into penis. The base of the penis is surrounded by unicellular **prostate gland**.

Female Reproductive System

A pair of small rounded ovaries or **germaria** is found at the anterior ends near the lateral borders. From each ovary leads an **oviduct** meeting posteriorly to form a common oviduct which later enters the genital atrium. Along the length of the oviduct open a number of follicular **yolk glands**. The yolk gland discharge yolk cells into the oviduct. On reaching the genital atrium the fertilized eggs together with yolk cells surround themselves with a hard capsule produced by the yolk cells themselves.

Two other structures open into the genital atrium—

(i) a stalked gland organ or muscular **copulatory sac** = **bursa copulatrix** which receives the penis of co-copulant during mating. This is not homologous to vagina of other flatworms.

(ii) a blind muscular sac stores fully formed shelled eggs. Although it functions as a uterus it is not homologous to the uterus of other flatworms.

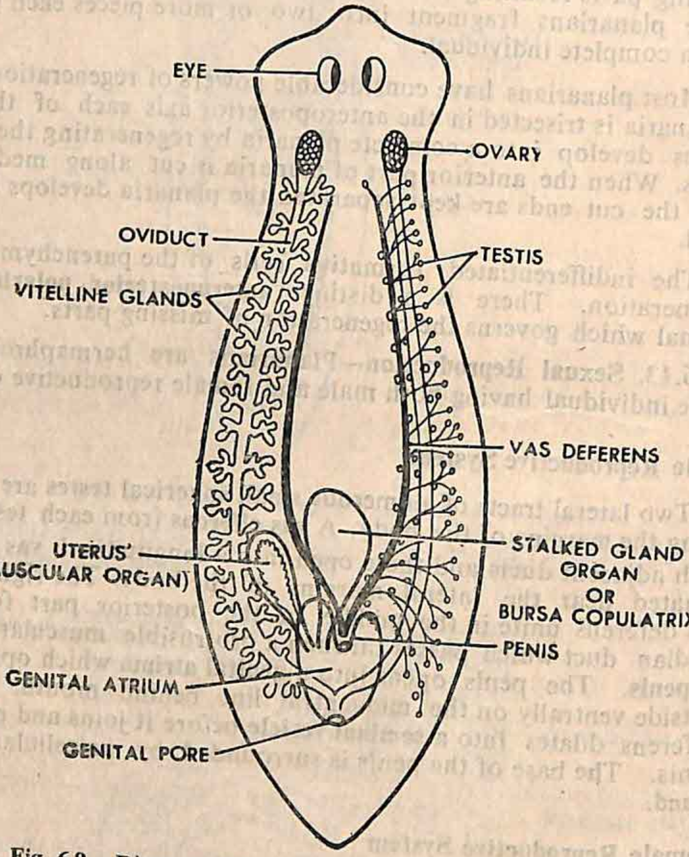


Fig. 6.9. Diagram of the reproductive system of a planaria. Vitelline glands shown only on left. Testes are shown only on the right side

6.14. Copulation—Although planarians are hermaphrodite cross fertilisation is habitually practiced. Copulation occurs by two planaria coming together by their posterior ventral surfaces. The penis of one individual is inserted into the genital atrium of the other individual for a reciprocal sperm transfer. Sperms are usually biflagellate and ascend up the oviducts where the eggs are fertilised. The eggs along with yolk cells and the shell cover are not stored in the so-called uterus but are laid in small groups in water. The prostate gland or cement gland contribute to the shell forming egg capsule in many planarians. In planarians yolk is located outside the egg in ectolecithal condition. Cleavage is largely spiral, the development is direct and young planaria emerge from the egg capsules in a few weeks.

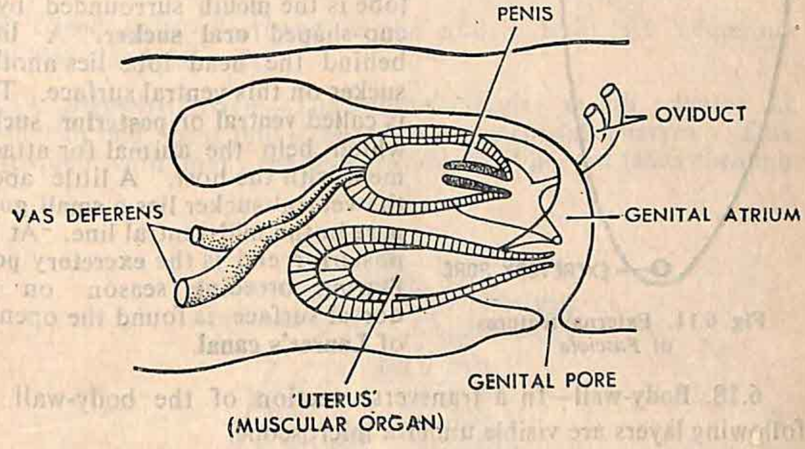


Fig. 6.10. Diagram showing the opening of vas deferens, oviduct, etc. in the genital atrium. Lateral view

FASCIOLA HEPATICA

(Liver-fluke)

6.15. Classification

Phylum—Platyhelminthes
Class—Trematoda
Order—Digena
Genus—*Fasciola*
Species—*F. hepatica*

6.16. Habit and Habitat—The adult *Fasciola* is found attached to the inner wall of bile duct and in liver of sheep, cow etc. As it is found in liver it is called **liver-fluke**. It causes a disease called **liver-rot**.

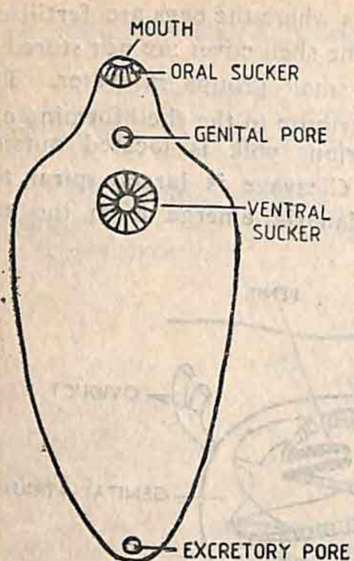


Fig. 6.11. External features of *Fasciola*

6.17. External Features—*Fasciola* is dorso-ventrally flattened, oval in shape like a leaf and faint brownish in colour. The anterior body part is broader than posterior part which is blunt in outline.

At the anterior end projects a conical structure called **head lobe** or **cephalic cone**. At the centre of this lobe is the **mouth** surrounded by a cup-shaped **oral sucker**. A little behind the head lobe lies another sucker on this ventral surface. This is called **ventral** or **posterior sucker** which help the animal for attachment with the host. A little above the ventral sucker lies a small **gonopore** in the mid-ventral line. At the posterior end is the **excretory pore**. During breeding season on the dorsal surface is found the opening of **Laurer's canal**.

6.18. Body-wall—In a transverse section of the body-wall the following layers are visible under a microscope.

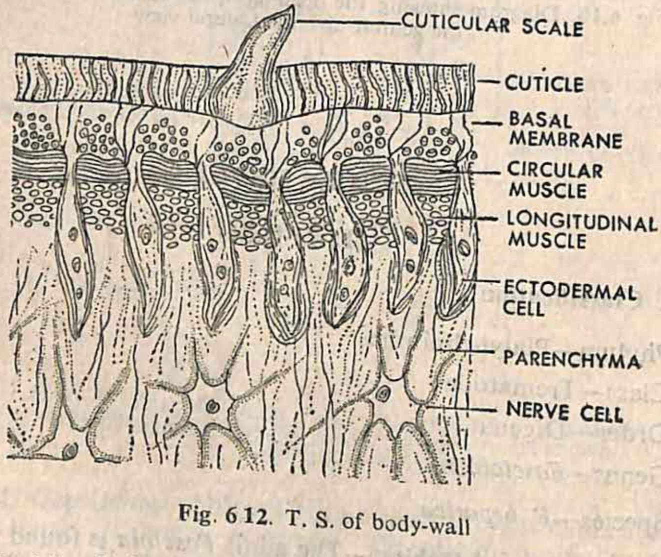


Fig. 6.12. T. S. of body-wall

(i) **Cuticle**—It is a homogeneous layer formed by scleroprotein and is provided with many small **spines**.

(ii) **Basement Membrane**—It separates the cuticle from underlying muscle layer.

(iii) **Muscle Layer**—It is formed by circular, longitudinal and diagonal muscles.

(iv) **Parenchyma**—The spaces between internal organs are filled by parenchymatous cells. These are large and branched cells. The branches of some of these cells reach the base of the cuticle.

(v) **Gland Cells**—Scattered in the muscle layer are numerous unicellular glandular cells.

6.19. **Digestive System**—The minute circular **mouth** situated at the anterior end opens into a muscular and suctorial **pharynx**. This is provided with many pharyngeal glands. Pharynx leads through a small narrow tube-like **oesophagus** into a bifid **intestine**. Each intestinal branch gives off many **caeca or diverticulae**. There is no **anus**.

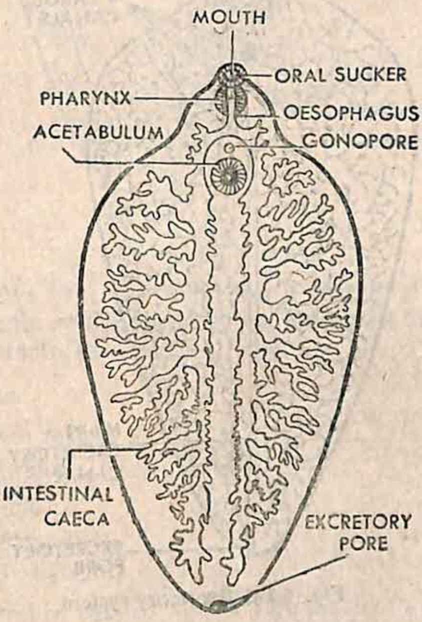


Fig. 6.13. Digestive system

6.20. **Excretory System**—From the posterior excretory pore extends an excretory canal up to 3/4 of the body. This canal is connected with two dorsal and two ventral excretory ducts situated at the anterior end.

Each excretory duct is connected with numerous special excretory cells called **flame cells.** Each flame cell is elastic with thin cell wall. There is an empty intercellular space in which lies a bunch of **vibratile cilia.** These cilia move constantly like a flame and help in moving excretory substances towards the excretory pore.

6.21. Respiratory System—As only anaerobic respiration takes place there is no special respiratory organs in *Fasciola.*

6.22. Circulatory System—Circulatory system is absent in *Fasciola.*

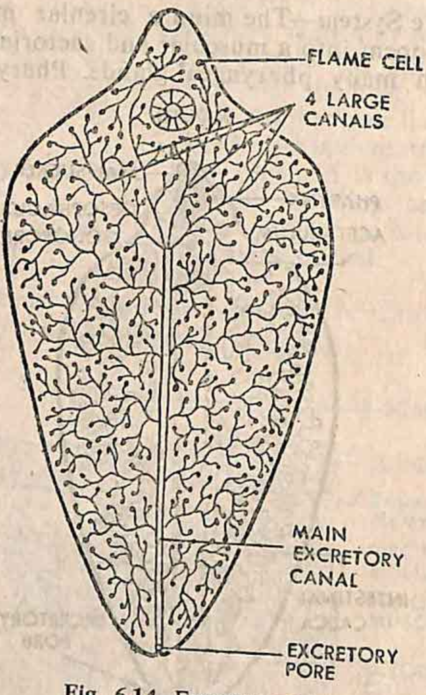


Fig. 6.14. Excretory system

6.23. Nervous System—It is characterised in having—

(i) a pair of cerebral ganglion which are connected by circum-oesophageal nerve ring.

(ii) nerves from cerebral ganglion go to head lobe and posterior part of the body.

(iii) a pair of lateral nerves and their branches extending up to the posterior end.

(iv) a **dorsal and ventral nerve** supply nerve to various internal organs.

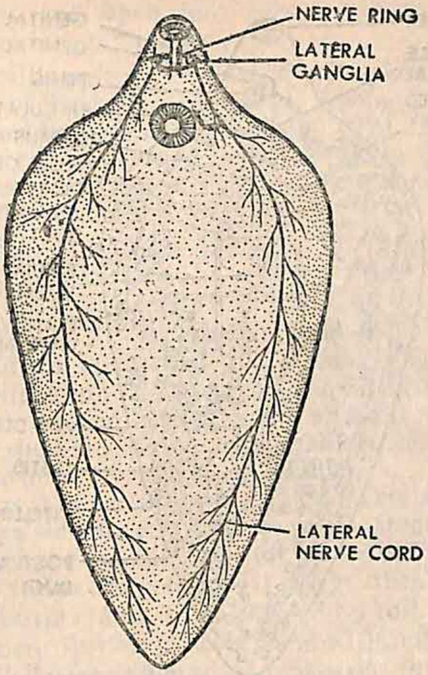


Fig. 6.15. Nervous system

6.24. Reproductive System--*Fasciola* is hermaphrodite and so both male and female genital organs are found in the same animal. There is only cross-fertilization.

Male Genital Organs

These are—(i) two testes,
(ii) two vas deferentia,
(iii) seminal vesicle,
(iv) one ejaculatory duct,
(v) cirrus and cirrus sac.

Testes are situated in the middle and posterior part of the body. These are extremely branched and lie one behind the other. From each testis comes out one **vas deferens** which unite to form a common sperm duct. This enlarges in front of ventral sucker to form a pear-shaped **seminal vesicle**. From this arises the thin zig-zag tube called **ejaculatory duct** which runs forward through cirrus to **genital chamber** where it opens to outside through **male genital aperture**.

The cirrus also called **penis** is a muscular cylindrical structure. This can be everted out and drawn inside through genital pore. Both cirrus and seminal vesicle lie within **cirrus sac.** Numerous prostate glands are present around ejaculatory duct.

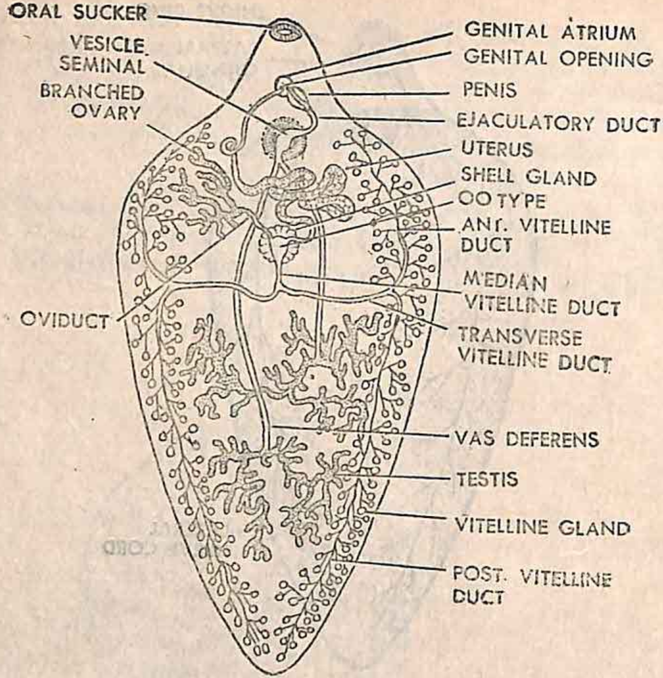


Fig. 6.16. Reproductive organs

Female Genital Organs

These are—

(i) one ovary,
(ii) one oviduct,
(iii) ootype,
(iv) uterus,
(v) shell glands with their ducts,
(vi) vitelline glands with their ducts, and
(vii) Laurer's canal.

The single ovary is tubular, highly branched structure lying on the right side in front of posterior testis. The **oviduct** comes out from the ovary and proceeds downwards. On its course it gives out the **Laurer's canal** which acts as a sperm duct and opens at the side of dorsal surface during breeding period. Then it joins with **median vitelline duct**. This point of union is swollen and is called **ootype** (it is said to be absent in *Fasciola hepatica*). The point of union or ootype is surrounded by numerous **shell glands** or **Mehli's glands**, the secretion of which forms shells around the eggs. From the ootype comes out the wide convoluted tube called **uterus**. This extends forwards and open into genital atrium by **female genital pore** beside the male genital pore.

Numerous **vitelline glands** also called **yolk glands** are found on each lateral side of the body. Fine ducts coming out from each join to form **lateral longitudinal vitelline** ducts. The two lateral longitudinal ducts are connected by **transverse vitelline duct** in the middle line. The **median vitelline** duct arises from the transverse vitelline duct which joins the oviduct.

6.25. Life-cycle—*Fasciola* is **digenetic**, i.e. it requires two hosts to complete its life-cycle. One is the primary host, the sheep or cow and the other is the intermediate host, the snail of genus *Limnaea*.

Within the body of the host the cirrus of one is introduced in the opening of Laurer's canal and the sperms migrate from here to uterus where fertilization takes place. The fertilised eggs get covered by yolk of vitelline glands and chitinous secretion of shell glands form the shell around the eggs. The covering of the egg or capsule has an opening covered by **operculum**.

Within uterus the fertilized egg by complete and unequal division forms a large **somatic** cell and a small **propagatory** cell. By repeated divisions the somatic cell forms the body of the larva and propagatory cell forms the germ cells. Eggs then pass through bile ducts, reach intestine and are deposited on soil with faeces of the host. Development further proceeds and within 9-20 days forms a ciliated larva called **miracidium** which comes out through the opening of egg capsule in water.

6.26. Miracidium Larva—This is the first larva formed in the life-cycle of *Fasciola*. It is a free-swimming, ciliated larva with broader

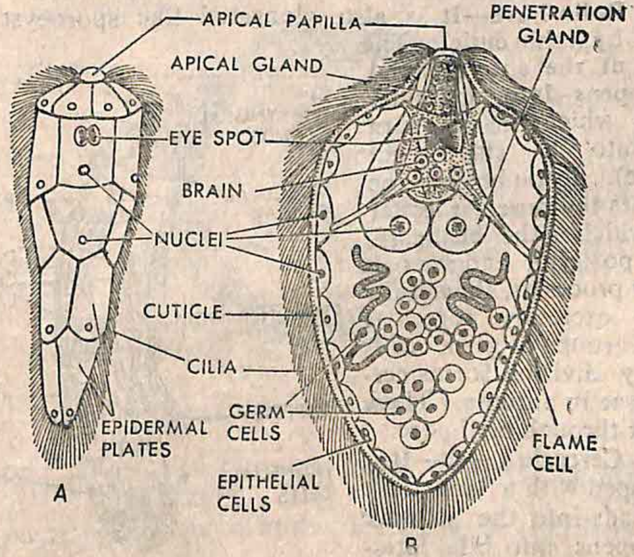


Fig. 6·17. Miracidium larva (A); detailed internal structures (B) anterior end which is provided with a conical projection called **apical lobe**. The posterior end is narrow and slightly conical. The entire body except the apical lobe is covered by **cilia**.

The ectoderm is formed by 21 hexagonal cells arranged in 5 rows (6+6+3+4+2) below which is the muscular layer. It has a brain, eye-spots arrange like 'X', a pair of protonephridia and a group of germ cells.

Miracidium larva swims freely in search of the intermediate host, *Limnaea*. It can live for 20-30 hours. If it fails to find out the host it dies. If it comes in contact with *Limnaea* it penetrates the host's soft body and reaches the pulmonary chamber. From here it comes to the digestive gland and throws off the cilia and changes to the second larva called **sporocyst larva**.

6.27. Sporocyst Larva—It is an elongated sac-like structure covered by cuticle. It contains protonephridia and germ cells which by division form redia larvae or daughter sporocyst. The redia larvae when full formed come out by rupturing the sporocyst wall.

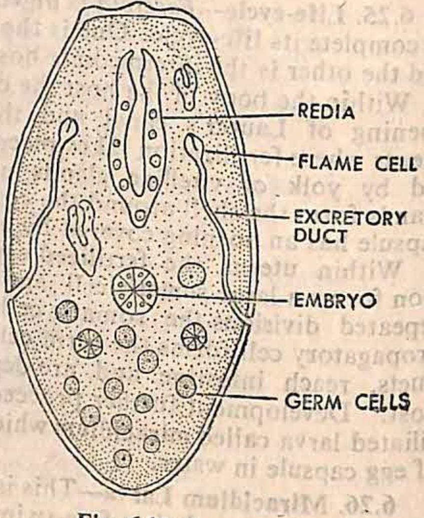


Fig. 6.18. Sporocyst larva

6.28. Redia larva—It is also elongated like sporocyst and is bounded by a thin cuticle. The mouth is at the anterior end which opens into muscular **pharynx**, which in its turn opens into a small **gut** (intestine). Little behind the pharynx is the **muscular collar** behind which is the **birthpore**. At the posterior end are two posterier processes, above each lies the excretory pore. It contains groups of germ cells which by division forms **cercaria larvae** in autumn. These come out through birthpore.

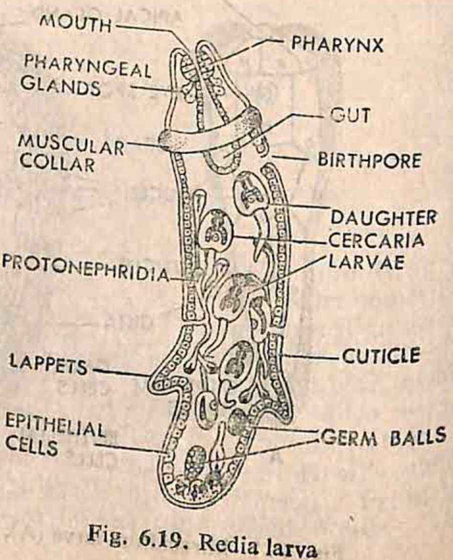


Fig. 6.19. Redia larva

6.29. Cercaria Larva—It is heart-shaped with a long tail. **Mouth** leads into the **pharynx** which opens into bifid **intestine**. Oral and ventral suckers are also present. The body contains **flame cells** (protonephridia), **germ cells** and **gland cells** (cystogenous gland cells).

When fully formed it comes out of snail body in water and finally gets attached on some aquatic plant. Here the tail disintegrate and it becomes covered by a cyst secreted by gland cells. This is **metacercaria stage.**

6.30. Metacercaria—It is round and protected by cyst wall. The mouth is at the centre of the oral sucker. Pharynx and bifid intestine are present. The flame cells increase in number.

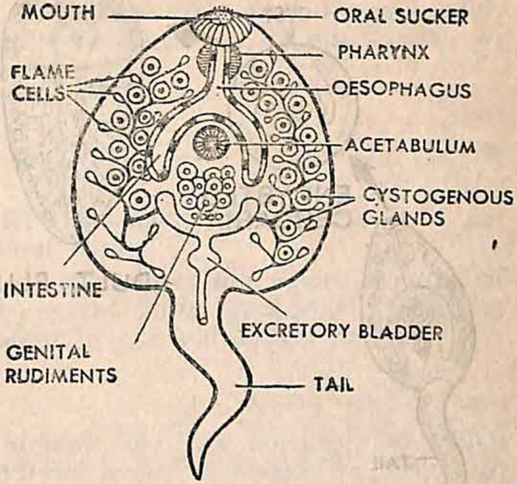


Fig. 6.20. Cercaria larva

Finally the metacercaria along with aquatic leaves reach the intestine of the host when it feeds upon aquatic plants. Here the

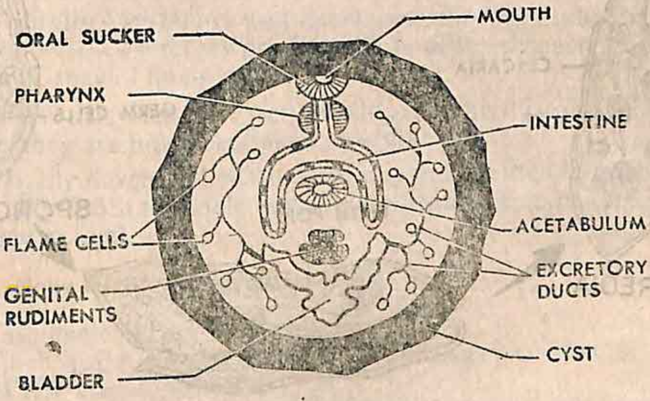


Fig. 6.21. Metacercaria larva

cyst is dissolved and the young fluke reaches the liver through hepatic portal system and continue the life-cycle (Fig. 6.22, page 248) after maturation and egg lying.

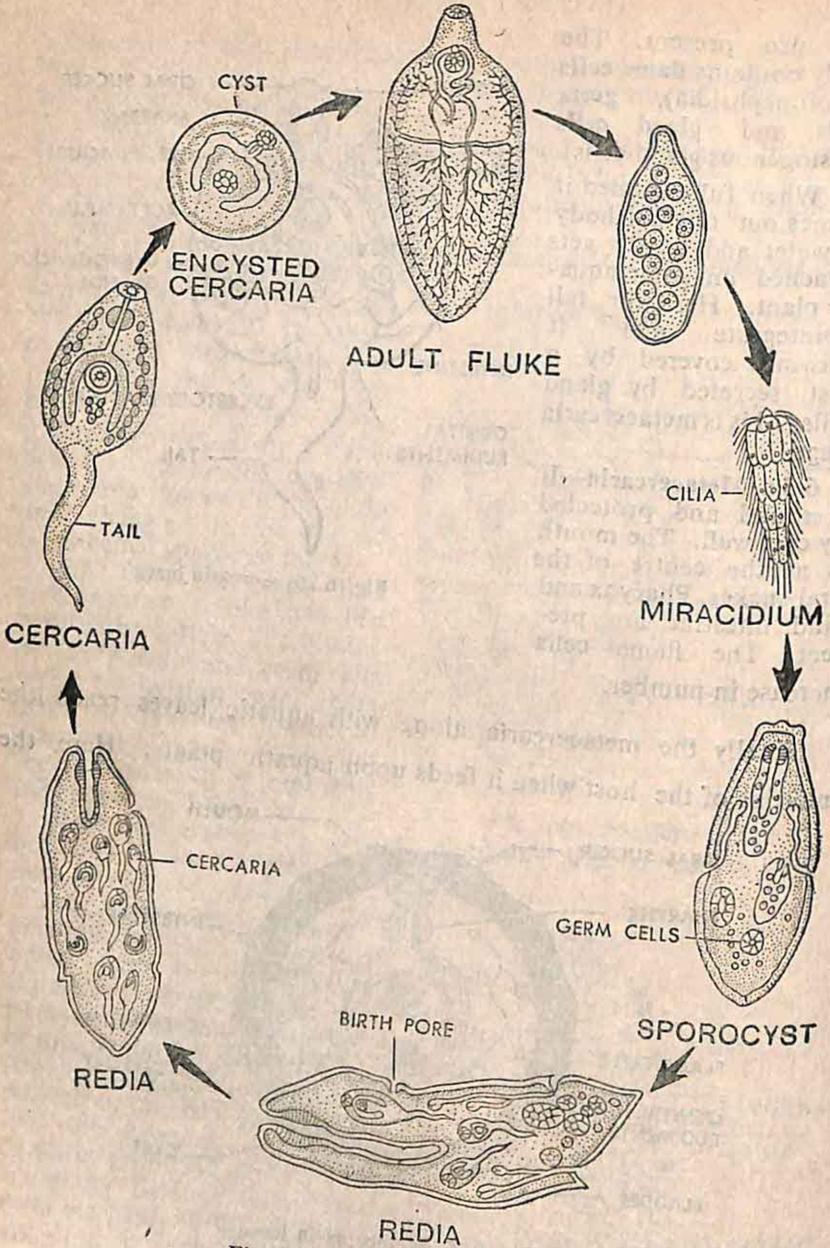


Fig. 6.22. Life-cycle of *Fasciola*

6.31. Parasitic adaptations in Liver-fluke—Parasitism is the association between two organisms of the same or different species in which one lives on or inside the body of the other and obtains food and nourishment causing harm to this organism. The organism which is thus benefitted from such association is called **parasite** and the other which is harmed is known as **host**. For example, the liver-fluke is the parasite while the sheep and snail are the hosts. Due to such parasitic life liver-fluke has undergone different kinds of adaptations for its survival. These are the following—

1. Morphological Adaptations

(i) The shape of the body is flat like a leaf so that it can live within the bile duct.

(ii) Presence of suckers for attachment. Due to this it is not easily dislodged from its natural habitat.

(ii) Cilia or any kind of appendages are absent. Absenec of locomotory organs in adult but the larva (miracidium) possesses cilia as it requires to move about in search of its host (snail).

2. Anatomical Adaptations

(i) On the body-wall presence of thick homogeneous **cuticle** which protects the animal from the action of digestive juice of the host.

(ii) Digestive system is not well developed. Highly branched intestine and there is no anus. This is because the animal gets already digested food and there is no need of egestion.

(iii) As it receives digested food which can pass on from one cell to other by diffusion there is no circulatory system.

(iv) There is no special respiratory organs as it gets little oxygen inside the body and it respires **anaerobically**.

(v) Excretory system is well developed, the longitudinal excretory canals can collect excretory products from different parts of the body by means of special flame cells.

(vi) Nervous system not well developed. There is no special sense organs as they are not essential in their habitat.

(vii) Highly developed reproductive system is the characteristic of parasitic life. Both the male and female genital organs are present in the same animal.

3. Adaptations in the Life-cycle

(i) Life-cycle is complicated.

(ii) Each produces large number of eggs so that if some are destroyed few may continue the cycle.

(iii) Eggs are protected by **shell** so that they are not easily destroyed on terrestrial or aquatic medium.

(iv) Many types of larvae are formed; miracidium can move about by cilia and can enter the intermediate host *Limnaea.* The next larval forms are sporocyst and redia. These show the phenomenon of **paedogenesis** i.e., they reproduce the next larval forms from germ cells within their body. Thus they ensure their continuance of life-cycle. They also show some sort of adaptations to pass over unfavourable condition. For example, when cercaria is formed is gets itself encysted for protection.

(v) Presence of an intermediate host ensures **dispersal** of the species from one place to another.

In short, this production of a large number of eggs, development of different larval forms and requirement of an intermediate host ensures the continuity and dispersal of the parasite.

4. Physiological Adaptations

(i) The osmotic pressure of the body fluid of the host and the medium in which it lives is the same. This prevents unnecessary loss of water.

SCHISTOSOMA

6.32. The best known trematode parasitic in blood of man and causing a dreadful disease is *Schistosoma*. This dioecious digenetic trematode in which the male and female worms live permanently paired together causes **Bilharziasis** or **Schistosomiasis**. No other disease caused by animal parasite causes as much harm to man as *Schistosoma* does with the sole exception of *Plasmodium* causing malaria. Three species namely, *Schistosoma mansoni*, *S. japonicum* and *S. haematobium* are commonly known.

They differ amongst themselves in minor details of structure and life-cycle. *S. haematobium* is found in Africa specially in Egypt and Sudan where up to 90% of the rural masses may carry the infection. The intermediate host is the freshwater snail *Bulinus truncatus* and related species of *Bulinus*. *S. japonicum* is found in the Far East (China, Japan, Philippines, Thailand, Vietnam etc.). The mollusc host for *S. japonicum* are species of the snail genus *Oncomelania*.

S. mansoni is found in many parts of Africa (including Egypt) and Tropical America including West Indies. The snail host of this species belongs to the genus *Biomphalaria*.

SCHISTOSOMA HAEMATOBIUM

6.33. **Structure**—The adult worms are beautifully adapted to life in blood vessels. The mature worms, male and female, live *in copula* (in almost permanent copulation) mainly in the branches of the inferior mesentric veins of man.

The male is flat 8-16 mm long and about 0·7 mm thick. The side of its body are rolled ventrally to form a **gynecophoric canal** in which the longer but more slender and almost cylindrical body of the female is enclosed. The anterior and posterior ends of the female project out of this canal. In *S. heamatobium* this union is permanent. The female worm becomes sexually mature only after it becomes associated with the male, the males mature even before the union has taken place.

Both male and female have **oral** and **ventral suckers**, the ventral suckers being large and more powerful in the male. The suckers serve to maintain the position of the worms in the blood vessel. The cuticle of the male is covered with minute papillae.

Mouth is situated in the centre of the oral sucker. The digestive tract lacks a pharynx, the oesophagus forks anterior to the ventral sucker, the two branches reunite in the middle of the body and extend to the posterior end as a median narrow canal. A pair of oesophageal gland surrounds the unbranched anterior part of the gut.

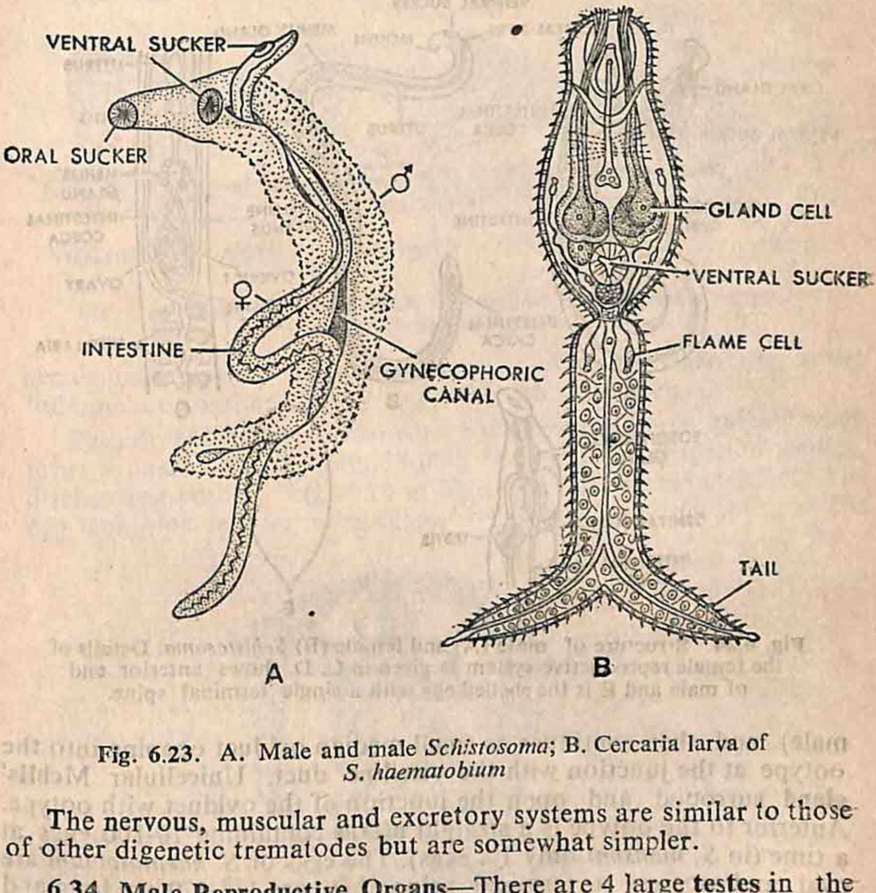


Fig. 6.23. A. Male and male *Schistosoma*; B. Cercaria larva of *S. haematobium*

The nervous, muscular and excretory systems are similar to those of other digenetic trematodes but are somewhat simpler.

6.34. Male Reproductive Organs—There are 4 large **testes** in the anterior part of the body behind the ventral sucker (in *S. monsoni* 6-9 testes are present). Four efferent ducts coming out of each testis meet to form a **vas deferens.**

The vas deferens swells to form a **seminal vesicle** opening by a non-muscular **cirrus** into the **genital pore** situated just behind the ventral sucker.

6.35. Female Reproductive Organs—The single **ovary** in *S. haematobium* is situated in the posterior third of the body in the place where the intestinal branches rejoin. It is elongated in shape. The **vitellaria** (= **vitelline gland**) is situated behind the ovary and extends to the posterior tip of the worm. The vitellaria are more extensive in *S. mansoni*. There is a single **vitelline duct** on both sides of whcih the vitellaria are disposed. The duct leads anteriorily into an **ootype.** From the ovary an **oviduct** emerges which immediately dilates into a swelling functioning as a **seminal receptacle** (receiving sperms from male) and then continues as small median oviduct opening into the ootype at the junction with the vitelline duct. Unicellular **Mehlis' gland** surround and open the junction of the oviduct with ootype. Anterior to the ootype is a straight **uterus** containing 10-100 eggs at a time (in *S. mansoni* only 1·4 eggs). The eggs of *S. haematobium* are oval and possess a terminal spine, they are 115-170 μm long and 45-65 μm broad. The shape of the egg used diagnostically is different in three species of blood fluke found in man. The shape of the egg is determined by the shape of the ootype. The blood flukes are unique among the trematodes in producing relatively smaller number of eggs at a time. They however compensate for this by being alive for a number of years in man. The eggs are fertilised in the oviduct and covered by shell along with yolk in the ootype.

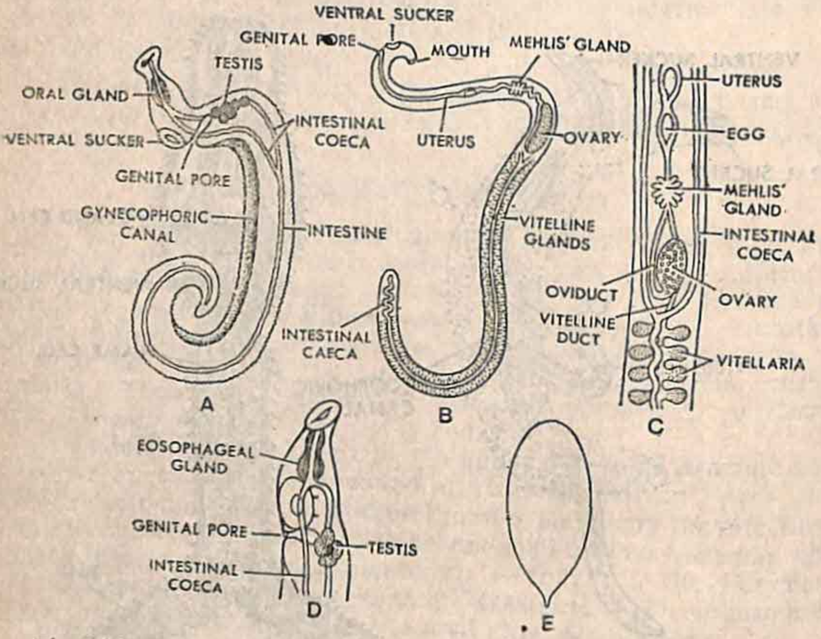


Fig. 6.24. Structure of male (A) and female (B) *Schistosoma*. Details of the female reproductive system is given in C. D. shows anterior end of male and E is the shelled egg with a single terminal spine.

6.36. Life-cycle—When eggs are to be deposited the female worm forces her slender body into as small a blood vessel as possible and lays the egg one by one at a time. The egg is laid in the small diameter blood vessels with the spine pointing backwards. The eggs gradually come out of the blood vessels into the wall of the urinary bladder aided with the spine and with the help of histolytic secretion. They finally pass out with the urine. Some of the eggs may be accidentally carried to other tissues and organs where they cause inflammation and are finally trapped in fibrous tissue.

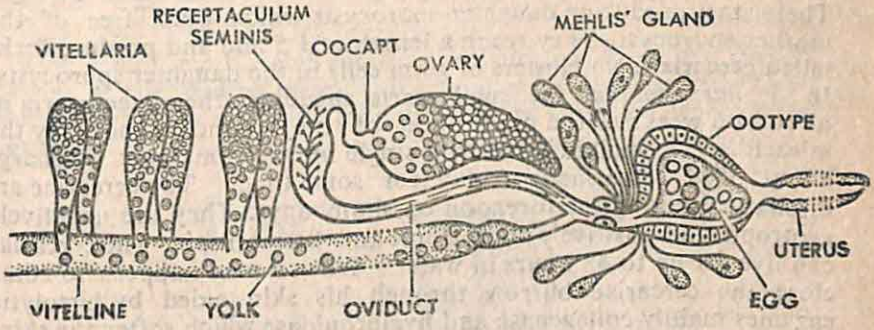


Fig. 6.25. The female reproductive system with components taking part in formation of yolky shelled eggs

Eggs do not hatch in the urinary bladder but hatch quickly when urine is passed out and gets diluted in water in irrigation canals, ditches and pools. Exposure to light also facilitates hatching. The egg contains mature **miracidium** which are also dioecious like the adult. The miracidia possess an **apical gland,** two **penetration glands, flame cells** and cluster of **germ cells**. The diagram of a shelled egg and meracidium of *Schistosoma* is given Fig. 6.24E and Fig. 6.26.

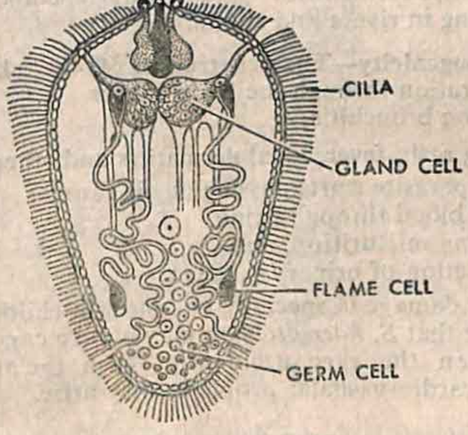


Fig. 6.26. Miracidium larva of *Schistosoma*

The miracidium cannot survive in water for more than 24 hours. It must find a snail *Bulinus truncatus* or a closely related species.

The miracidia burrow through the viscera to the digestive gland, losing their ciliated covering and changing into a tubular **sporocyst**. The times for various development stages for *S. haematobium* is not known. In *S. mansoni* the **sporocyst** grow to 1 mm in about 14 days. These start producing daughter sporocysts which burst free of the mother sporocyst. They reach a length of 1·5 mm and produce fork-tailed **cercaria** from clusters of germ cells in the daughter sporocysts. In *S. haematobium* the snail starts shedding the metacercaria in about 4-6 weeks of the penetration of the secondary host by the miracidia. A snail infected by a single miracidium may discharge about 3500 cercariae per day for some time. The cercariae are discharged during the forenoon on sunny days. They are negatively geotropic and positively phototropic and thermotropic. The cercariae can live for up to 48 hours in water. When a man happens to come close the cercariae burrow through his skin aided by histolytic enzymes mainly collagenase and hyaluronidase which soften the skin. The cercariae reach the venous circulation either directly or through the lymph vessels. From the skin they first reach the heart and then the liver. From the liver they finally reach the mesenteric vessels. Sexual maturity and pairing is reached in 4-5 weeks of the penetration of human skin by cercariae and the eggs appear in the urine only after 10-14 weeks.

6.37. **Control of Schistosomiasis**—The control of this disease depends basically on the eradication of the intermediate host, the snail. Chances of entry of cercariae into human body can be reduced by improvement of personal hygiene and stoppage of the habit of bathing in rivers and streams.

6.38. **Pathogenicity**—The penetration of the skin by cercariae and their migration through the body causes

(a) irritating bronchitis,

(b) itching rash, fever, local dermatitis and other toxic symptoms.

When the parasite starts passing egg it causes

(c) loss of blood through urine,
(d) irritating micturition, and
(e) constriction of urinary passage.

Urological damage is specially common in children and there is some evidence that *S. haematobium* may induce cancer of the urinary bladder. When the egge accidently reach the arteries of lung or heart serious cardio-vascular problems may arise.

TAENIA SOLIUM

(The Common Tape-worm)

6.39. Classification

Phylum—Platyhelminthes
Class—Cestoidea

Sub-class—Cestoda
Order—Cyclophyllidea
Family—Taeniidae
Genus—*Taenia*
Species—T. solium

6.40. Habit and Habitat—It is an endoparasite found in the intestine of pork-eating people. It gets attached with mucosa by its hooks and suckers while the long body hangs freely in the lumen of intestine.

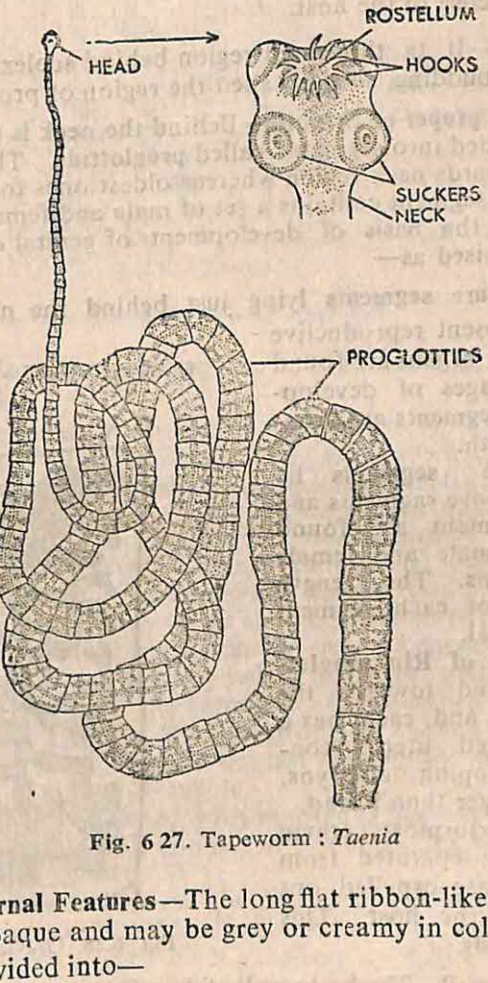


Fig. 6 27. Tapeworm : *Taenia*

6.41. External Features—The long flat ribbon-like body is about 3-5 metres, opaque and may be grey or creamy in colour. The body is distinctly divided into—

(i) head or scolex,
(ii) neck, and
(iii) strobila or body proper.

(i) **Head**—The head or scolexrepresents the anterior part of the body and is of the size of a pin-head. It has two parts—

(a) **Rostellum**—It is the anteriormost part and is characterised in having 28 hooks arranged in two rows at its base. The hooks are of two sizes and are curved chitinous structures. The smaller hooks alternate with larger ones.

(b) **Distal part**—It is characterised in having 4 suckers—one dorsal, one ventral and one of each lateral side.

Hooks and suckers help the animal to attach the animal with the intestinal mucosa of the host.

(ii) **Neck**—It ts the small region behind scolex. It forms new segments by budding, so it is called the region of proliferation.

(iii) **Body proper or Strobila**—Behind the neck is the long body which is divided into segments called **proglottids**. The youngest segments lie towards neck region whereas oldest ones towards posterior region. Each segment contains a set of male and female reproductive organs. On the basis of development of genital organs this part can be recognised as—

(a) **Immature segments** lying just behind the neck with either completely absent reproductive organs or the organs are found at different stages of development. The segments are broader than length.

(b) **Mature segments** lie behind the above sagments and in each segment are found both mature male and female genital organs. The length and breadth of each segment is almost equal.

(c) **Gravid of Rip progiottids** are found towards the postrior end and each has a much branched uterus containing developing embryos. These are longer than broad.

The posteriormost gravid proglottids are separated from the body and are expelled out with faeces of the host. This is called **apolysis**.

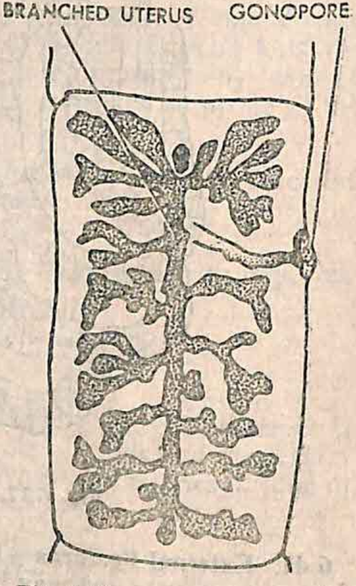


Fig. 6.28. Gravid proglottid

6.42. **Body-wall**—The body-wall of *Taenia* has the following layers:

(i) **Cuticle**—It is the outer thick covering formed by protein and calcium salts. It has an outermost layer with hair-like processes.

a middle thick homogeneous layer and a lowermost thin basement membrane.

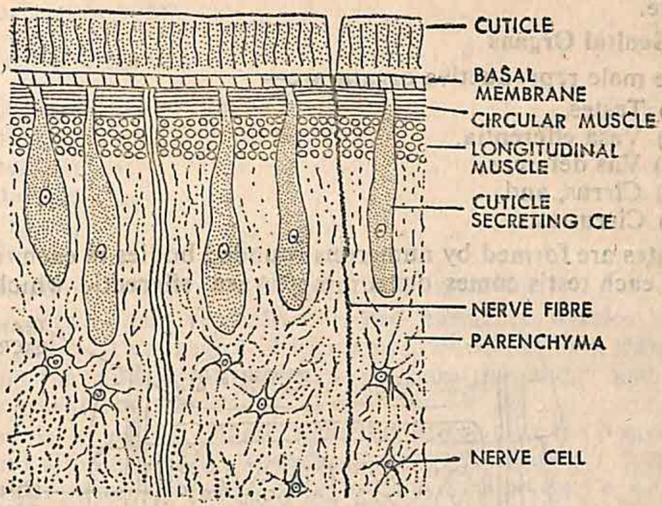


Fig. 6.29. T. S. of body-wall

(ii) **Muscular Layer**—Below cuticle is the circular and longitudinal muscle layers.

(iii) **Parenchyma**—The whole body cavity is filled with loose parenchymatous cells. In this are found many sac-like gland cells, vertical muscles, nerve fibres and many sub-cuticular cells.

6.43. **Digestive System**—There is no digestive organs and glands. It absorbs digested food from the intestine of host by diffusion.

6.44. **Respiratory System**—There is no special respiratory organs as anaerobic respiration takes place in **Taenia.**

6.45. **Excretory System**—This system is well developed in **Taenia.** It consists of 4 lateral excretory canals—two are **dorsal** and are found in the anterior segments only while two are **ventral** and extend throughout the length of the animal. They are joined by **transverse excretory canals** lying at the posterior part of each segment. The lateral excretory canals unite in the last segment to form the **caudal vesicle** which opens to the outside.

Each canal is connected with numerous **flame cells.** The inner space of each flame cell is connected by connecting vessels with the lumen of excretory canals.

6.46. **Nervous System**—At the anterior end are two **cerebral ganglia** which are connected by dorsal and ventral commissures forming a nerve ring. From each ganglion nerves are given off to the suckers and rostellum. Three pairs of longitudinal nerves are given out from these ganglia. One pair of longitudinal nerves extend along the outerside of lateral excretory canal throughout the length of the animal.

6.47. Reproductive System—In each mature proglottid there is a set of male and female reproductive organs. So *Taenia* is **hermaphrodite.**

Male Genital Organs

The male reproductive organs are—

(i) Testes,
(ii) Vasa efferentia,
(iii) Vas deferens,
(iv) Cirrus, and
(v) Cirrus sac.

Testes are formed by numerous rounded bodies in each segment. From each testis comes out a minute **vasa efferentia** which join to form a common **vas deferens.** This extends either to the left or to the right to open into **genital atrium.**

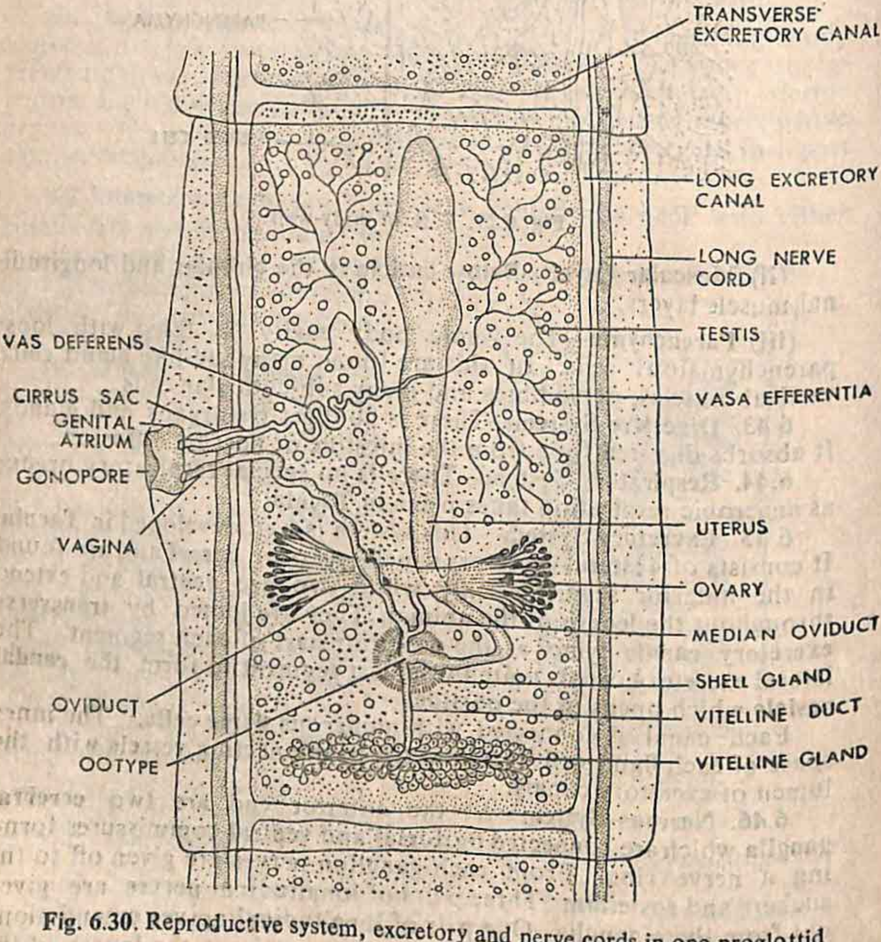


Fig. 6.30. Reproductive system, excretory and nerve cords in one proglottid

The terminal part of vas deferens is called **cirrus** which extends through muscular **cirrus sac** and opens into genital atrium by male genital pore (gonopore).

Female Genital Organs

Female reproductive organs include—
(i) Ovaries,
(ii) Oviduct,
(iii) Ootype,
(iv) Vagina,
(v) Uterus,
(vi) Glands—vitelline and shell (Mehlis) glands.

There are two dorso-ventrally flattened, branched **ovaries** at the posterior end of the proglottid which are connected by a **transverse bridge** from the middle of which originates the short and wide **oviduct** to join the **ootype**.

Ootype is a round, small chamber formed at the junction of oviduct and vitelline duct. **Vitelline gland** is a compact follicular gland at the posterior end of ovary. The **vitelline duct** opens into ootype. The secretion of vitelline gland forms an yolk covering around fertilized eggs. The ootype is surrounded by many **shell glands** or **Mehlis' glands**.

Uterus arises as a blind sac-like tube from ootype and runs towards anterior end of the proglottid.

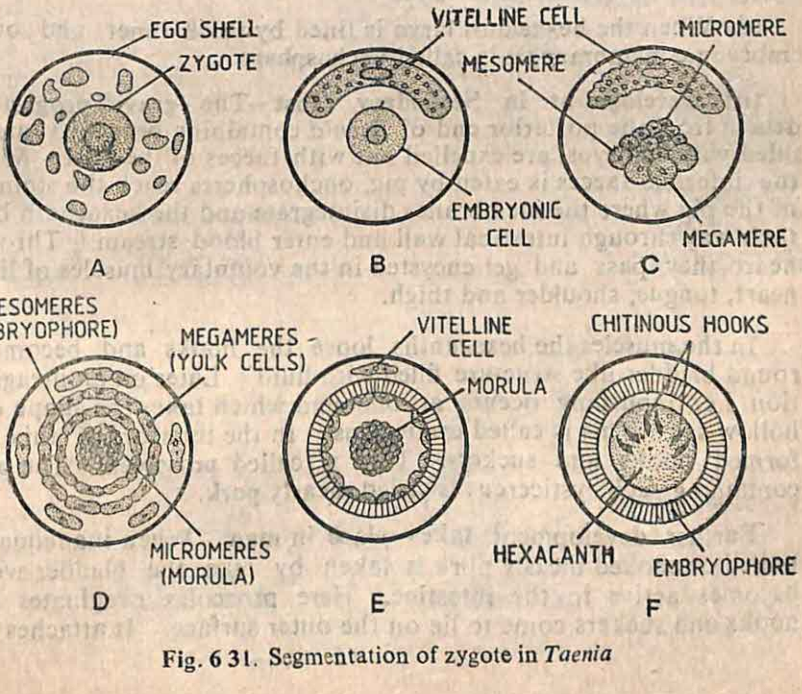


Fig. 6 31. Segmentation of zygote in *Taenia*

Vagina is the extension of the **receptaculum seminis** which is a short wide tube arising from ootype. It runs towards lateral side to open into **genital atrium** by gonopore (female genital opening).

The genital atrium opens alternately on the lateral side by a common **gonopore.**

6.43. Life cycle—(i) Fertilization—Fertilization occurs by introducing the cirrus into the vagina of the same proglottid and sperms are stored in the receptaculum seminis, which later on fuse with eggs in uterus. Thus in *Taenia* self-fertilization takes place.

Eggs become covered by yolk and egg shell while passing through ootype and are stored in uterus.

(ii) Segmentation—The division of the egg occurs in uterus. The first division is unequal resulting in a large **vitelline** and a small **embryonic cell**. The embryonic cell by repeated unequal divisions form a solid ball stage called **morula**. The larger cells are called **megameres** while smaller cells are known as **micromeres**. The vitelline cell along with yolk provide nourishment to the developing embryo and gradually decrease.

(a) The mega- or macromeres form the outer embryonic membrane.

(b) The micromeres cut off few **mesomeres** which form the inner thick striated membrane which is also called **embryophore**.

(c) From the remaining micromeres are formed six chitinous hooks which are called **hexacanth**

(d) When the hexacanth larva is lined by thick inner and outer embryonic membrane, it is called **onchosphere**.

(iii) Development in Secondary Host—The gravid proglottids detach from the posterior end of *Taenia* containing branched uterus filled with embryos, are expelled out with faeces of the host. When the infected faeces is eaten by pig, onchospheres reach the stomach of the pig where the membranes disintegrate and the hexacanth bore their way through intestinal wall and enter blood stream. Through heart they pass and get encysted in the voluntary muscles of liver, heart, tongue, shoulder and thigh.

In the muscles the hexacanths loose the hooks and become a round bladder-like structure filled with fluid. Later on an invagination i.e. inpushing occurs at one end which takes the shape of a hollow sac. This is called **cysticercus**. In the interior of this are formed hooks and suckers. This is called **proscolex**. The pork containing such cysticercus is called **measly pork**.

Further development takes place in man. When inadequately boiled or cooked measly pork is taken by man the bladder-worm becomes active in the intestine. Here proscolex evaginates and hooks and suckers come to lie on the outer surface. It attaches the intestinal wall by scolex and proglottids begin to bud off from the neck region and ultimately form a long ribbon-like body consisting of many proglottids. The bladder attached with scolex is separated and digested. The parasite takes 2½-3 months to become mature.

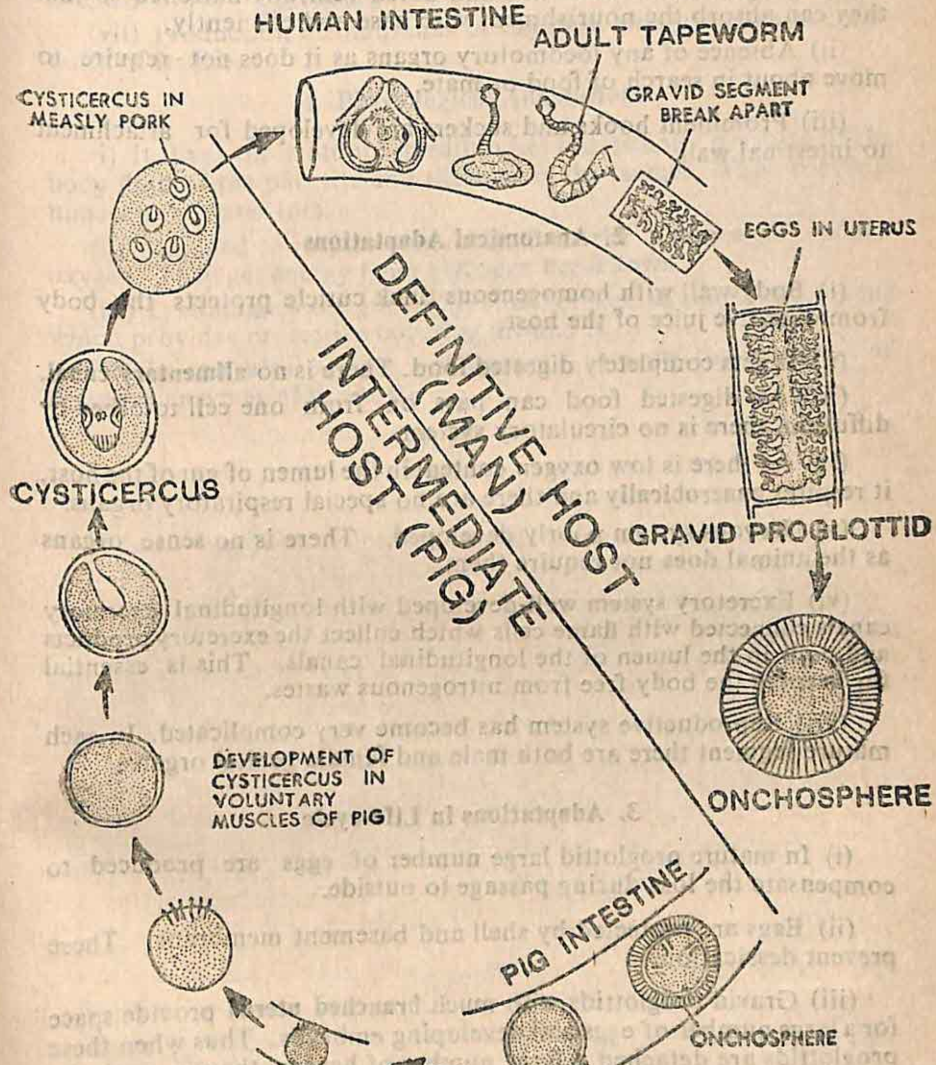


Fig. 6.32 Life-cycle of *Taenia*

6.49. Parasitic Adaptations in Taenia

1. Morphological Adaptations

(i) As it hangs from intestinal wall it becomes elongated due to many proglottids, ribbon-like and dorso-ventrally flattened so that they can absorb the nourishment with ease and efficiently.

(ii) Absence of any locomotory organs as it does not require to move about in search of food or mate.

(iii) Prominent hooks and suckers are developed for attachment to intestinal wall.

2. Anatomical Adaptations

(i) Body-wall with homogeneous thick cuticle protects the body from digestive juice of the host.

(ii) It gets completely digested food. There is no **alimentary canal.**

(iii) As digested food can pass on from one cell to other by diffusion, there is no circulatory system.

(iv) As there is low oxygen content in the lumen of gut of the host, it respires **anaerobically** and there are no special respiratory organs.

(v) Nervous system poorly developed. There is no sense organs as the animal does not require them.

(vi) Excretory system well-developed with longitudinal excretory canals connected with flame cells which collect the excretory products and pour in the lumen of the longitudinal canals. This is essential for keeping the body free from nitrogenous wastes.

(vii) Reproductive system has become very complicated. In each mature segment there are both male and female genital organs.

3. Adaptations in Life-cycle

(i) In mature proglottid large number of eggs are produced to compensate the loss during passage to outside.

(ii) Eggs are protected by shell and basement membrane. These prevent dessication.

(iii) Gravid proglottids with much **branched uterus** provide space for a large number of eggs and developing embryos. Thus when these proglottids are detached a large number of hexacanths can reach the stomach of the secondary host.

(iv) Hexacanth with **six chitinous hooks** adapted for attachment. It is also with penetration glands which help the hexacanth to penetrate the intestinal wall of pig (secondary host) and can reach blood circulation.

(v) Cysticercus or bladder-worm can protect itself in muscles as it **encysts** itself.

(vi) The presence of a secondary host ensures its **dispersal** which is essential for its existence.

(vii) Production of thousands of eggs and embryos ensures continuity of its life.

4. Physiological Adaptations

(i) It lives in isotonic medium i.e. the osmotic pressure of the body fluid of the parasite and the host is the same. This prevents unnecessary water loss.

(ii) Modified to respire anaerobically in the absence of enough oxygen. They get energy from glycogen breakdown.

(iii) It stimulates the gut of the host for the secretion of mucus which provides protective covering around it.

(iv) It can also secrete anti-enzyme to neutralize the effect of digestive enzymes of the host.

□□□

7. PHYLUM : ASCHELMINTHES

(Nemathelminthes)

7.1. **Characters**—(i) These are small thin animals being **triploblastic** and **acoelomata.**

(ii) Body is bilaterally symmetrical.

(iii) Unsegmented, elongated, mostly cylindrical body.

(iv) **Mouth** surrounded by lips is at the anterior end, **anus** at posterior end.

(v) Excretory system in the form of canals.

(vi) Sensory papillae and amphids form sense organs.

(vii) Sexes are separate; generally gonads are coiled.

(viii) These are oviparous or ovoviviparous.

7.2. **Classification**—It is divided into six **classes.**

Class 1. Rotifera—(i) These are generally called 'wheel animalcule' with trunk and tail forming the body proper.

(ii) A ciliated **trochal disc** at the anterior end for locomotion and food capture.

(iii) Male is smaller than female.

Ex. *Hydratina.*

Class 2. Gastrotricha—(i) Aquatic small animals with elongated thread-like body.

(ii) **Mouth** at the anterior end and is covered by **bristles.**

(iii) On the ventral surface two longitudinal rows of cilia which help in locomotion.

Ex. *Chaetonotus.*

Class 3. Kinorhyncha—(i) They are marine animals (1 mm long).

(ii) The body is cylindrical, formed by 11-12 rings covered by hard cuticle.

(iii) Head is formed by 2 rings.

(iv) Mouth with retractile proboscis.

(v) Sexes are separate.

Ex. *Echinodera.*

Class 4. Priapuloidea—(i) Marine animals, body like a saucer.

(ii) One spiny introvert at anterior end.

(iii) Straight alimentary canal; anus surrounded by gill-lobes at the posterior end.

(iv) Adult with circulatory system, excretory organ and sensory organs.

(v) Sexes are separate.

Ex. *Priapulus*.

Class 5. Nematomorpha—(i) During larval stage it is parasite in insect and during adult condition it leads free-swimming aquatic life.

(ii) Thread-like body with blunt anterior end.

(iii) Cuticle is transparent and rough.

(iv) Body cavity lined by cells.

(v) Male and female separate.

Ex. *Gordius*.

Class 6. Nematoda—(i) These are generally called round-worms.

(ii) They may be aquatic, terrestrial or parasitic.

(iii) Long cylindrical body is unsegmented and is tapering at both ends.

(iv) Body covered by thick cuticle.

(v) Below epidermis lies longitudinal muscles.

(vi) It has pseudocoel.

(vii) Complete alimentary canal; mouth at anterior end surrounded by lips.

(viii) Circulatory and respiratory systems absent.

(ix) Nervous system with nerve ring and six longitudinal nerve cords.

(x) Sexes are separate.

(xi) Variations in life-cycle : intermediate host may be one or two or absent.

This class is divided into two sub-classes—

Sub-class 1. Aphasmidia,
Sub-class 2. Phasmidia.

Sub-class 1. Aphasmidia—Sensory organs (phasmida) are found on the posterior region of the body.

Order 1. Chromadoridia—Oesophagus with three parts and oesophageal glands are not bilobed.

Ex. *Chromadora*.

Order 2. Anoploidea—Body with anterior glandular and posterior glandular part.

Ex. *Trichinella*.

Sub-class 2. Phasmidia—Sense organs (phasmida) are present at the caudal region.

Order 1. Rhabditoidea—Oesophageal parts and layers (three) are more distinct during larval stage.

Ex. *Ancylostoma* (hook-worm of man), *Ascaris*.

Order 2. **Spiruroidea**—Two-layered oesophagus.

Ex. *Wuchereria* (filaria worm of man). *Loa* (eye worm of man) etc.

7.2. (A) **Name of nematodes harmful to man**—

(i) *Ascaris lumbricoides*,
(ii) *Trichinella spiralis*,
(iii) *Ancylostoma duodenale*,
(iv) *Wuchereria bancrofti*,
(v) *Loa loa*.

ASCARIS LUMBRICOIDES

(Round-worm)

7.3. Classification

Phylum—Aschelminthes
Class—Nematoda
Order—Rhabditoidea
Genus—Ascaris
Species—*A. lumbricoides*

7.4. **Habit and Habitat**—It is one of the most commonly found nematode in all parts of the world and is generally called round-worm. It is an endoparasite of human intestine.

7.5. **External features**—It has a long cylindrical body with light pink or light yellow in colour. The sexes are separate and female is longer and stouter than the male.

The cylindrical body is pointed at both ends. A triangular **mouth** is situated at the anterior end of the body which is surrounded by three denticulate **lips** of which one is mid-dorsal and two are latero-ventral in position. On lips are found sensory papillae. Two such papillae on dorso median and one on each ventro-lateral lips. In addition on each ventro-lateral lip is found one **lateral papillae** beside which is one **cervical sensory papillae** or **amphid**. Four longitudinal **lines** are found along the mid-dorsal (dorsal line), mid-ventral (ventral line) and two lateral regions (lateral lines) of the body. A little behind the mouth on the ventral surface is the minute **excretory pore**.

The males and females can be recognized from the external characters. The male is shorter than female. The posterior part of the male is curve while the female has straight posterior part. The male has a cloacal aperture. Two chitinous spines called **penial setae** project through the cloacal aperture. The female has an **anus** a little in front of posterior end on the ventral surface. The **female genital aperture** lies on the ventral surface at about 1/3 of the body's total length from the anterior end. In male anterior to cloacal aperture there are 60 pairs of pre-cloacal papillae and posterior to cloacal aperture five pairs of papillae are present. These are also called **phasmids** and are helpful during copulation.

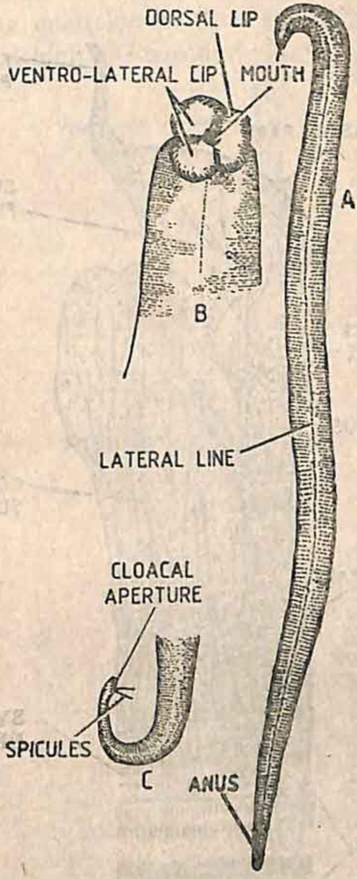


Fig. 7.1. *Ascaris* : A. female; B. anterior end; C. posterior end of male

7.6. **Body-wall**—The body-wall of *Ascaris* has the following layers. Starting from outside these are—

(a) **Cuticle**—It is soft and transparent and is formed by nine layers (Chitwood and Chitwood, 1950). It contains keratin, spongy protein, collagen fibres on which there is no effect of digestive juice of the host.

(b) **Epidermis**—*Ascaris* has an epidermal layer which is characterised in having no cellular boundary i.e., nuclei are scattered in the protoplasm. This type of epidermis is called **syncytial epidermis**.

(c) **Muscular layer**—Below epidermis is the characteristic longitudinal muscle layer, the continuity of which is broken due to dorsal, ventral and lateral lines, forming two dorso-lateral and two ventrolateral layers.

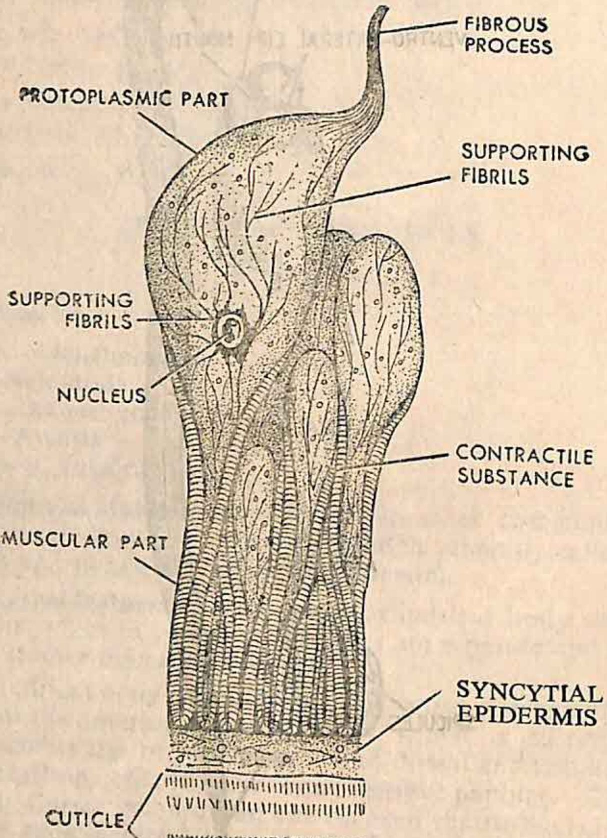


Fig. 7.2. Part of the body-wall showing muscle cells

Each **muscle cell** has an outer striated contractile part and an inner protoplasmic part containing **nucleus** and **fibrils**.

7.7. **Body-cavity**—The true body-cavity i.e., coelom is absent in *Ascaris*. During early development the body-cavity remains filled up with vacuolated **coelomocytes**. During latter part of development these cells disappear and their vacuoles fuse to form the body-cavity. As the body-cavity is not lined by cells of mesodermal origin it is called pseudocoel or pseudocoelom.

7.8. Digestive System—As *Ascaris* receives the half-digested food from lumen of the intestine of host, its alimentary canal is very simple.

The alimentary canal is a straight tube extending from **mouth** to **anus**. The mouth is encircled by three **lips**. The mouth opens into a muscular pharynx which has triradiate lumen lined internally by **cuticle**. The wall contains contractile **radial muscles**, three **gland cells** and connective tissues. Due to expansion of these muscles the lumen enlarges and the food of the host's intestine is taken in by the sucking action of the pharynx.

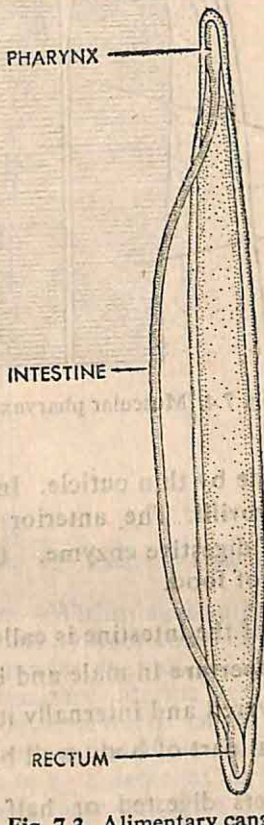


Fig. 7.3. Alimentary canal

Pharynx opens behind in a straight, thin-walled **intestine**. At the junction of pharynx and intestine is a **valve** which allows food to pass only from pharynx to intestine and not vice versa. The wall of intestine is formed by one layer of endodermal epithelial cells and is

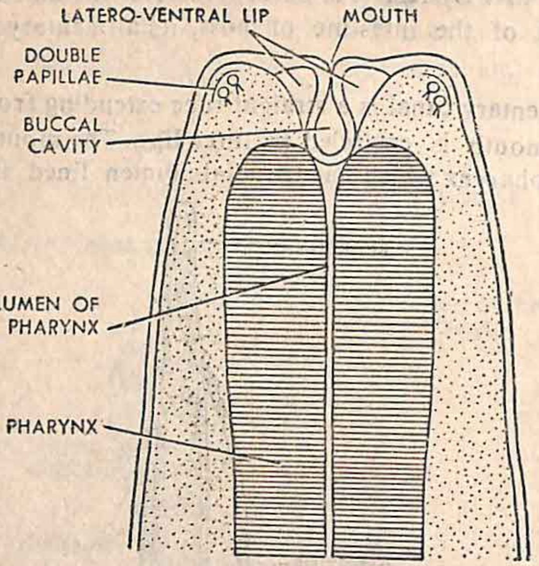


Fig. 7.4. Muscular pharynx

covered on the outer side by thin cuticle. Internally these cells are provided with many **microvilli**. The anterior part of the intestine secretes a special kind of digestive enzyme. In general the intestine takes part in absorption of food.

The posterior part of the intestine is called **rectum** which opens to outside by **cloacal aperture** in male and by **anus** in female. The wall of rectum is one-layered and internally it is lined by cuticle. It is connected with internal part of body-wall by **dilator muscles**.

Digestion—*Ascaris* gets digested or half-digested food from its host. So it does not require to digest food. However it can digest half-digested food by means of enzymes secreted by gland cells of pharynx and cells of anterior part of intestine. These enzymes can digest carbohydrates, proteins and fats.

Absorption—The cells of intestine generally absorb digested food. Excess fat and glycogen are stored in different tissue.

Egestion—By the contraction of dilator muscles attached to rectum undigested food is expelled out.

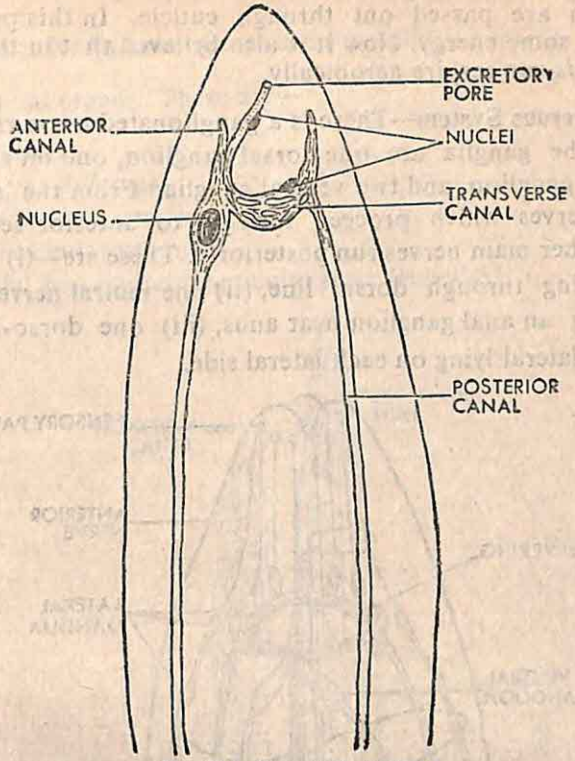


Fig. 7.5. Excretory system

7.9. Excretory System—Within each lateral line is a long **excretory canal** which are joined by finer canals below the pharynx called **transverse canals.** The posterior part of the long canal is called **posterior canal** while the part anterior to transverse canal is called **anterior canal.** From the transverse canal extends a small duct opening to outside by **excretory pore.** Thus a 'H'-shaped canal system is formed. It is to be noted that all these canals are formed from excavation in a single large cell. The nucleus of the cell lies at the anterior end of the left longitudinal canal. There are also two small nuclei of which one lies on the transverse bridge and the other on the terminal duct. These canals are without cilia and flame cells.

Due to pressure in body-fluid excretory products like urea enter this canal system by ultrafiltration from where they are expelled out through excretory pore.

7.10. Respiration—*Ascaris* lacks any special respiratory organs. The lumen of the intestine of their host contains little oxygen and so *Ascaris* respires by **anaerobic** method In this process glucose is first converted to **lactic** acid which later on forms CO_2 and fatty acids which are passed out through cuticle. In this process this animal gets some energy. Now it is also believed that in the presence of O_2 *Ascaris* can respire aerobically.

7.11. Nervous System—There is a ganglionated nerve ring around pharynx. The ganglia are one dorsal ganglion, one on each lateral side lateral ganglion, and two ventral ganglia. From the nerve ring arise six nerves which proceed forward to anterior sense organs while six other main nerves run posteriorly. These are—(i) one **dorsal nerve** running through dorsal line, (ii) one **ventral nerve** in ventral line forming an anal ganglion near anus, (iii) one dorso-lateral and one ventro-lateral lying on each lateral side.

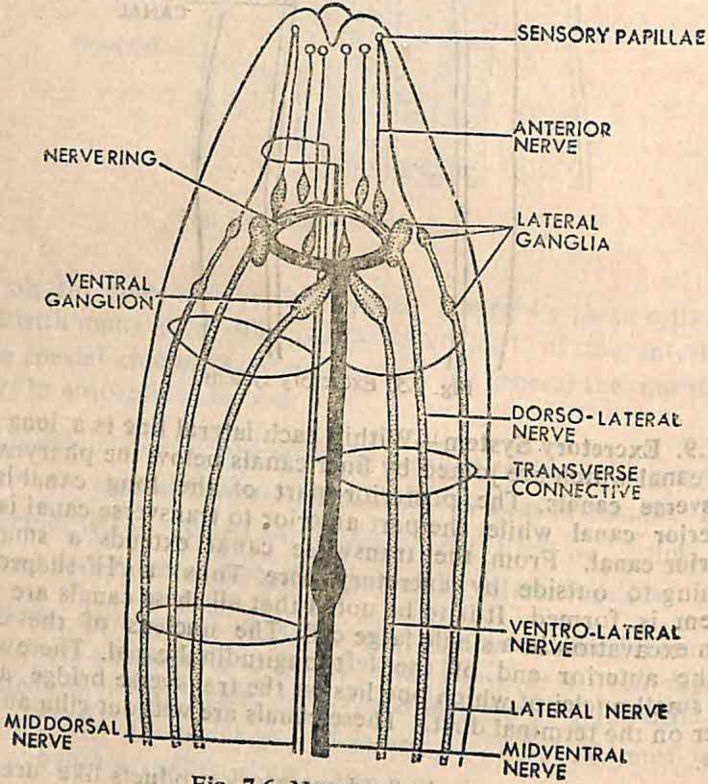


Fig. 7.6. Nervous system

In addition to the above six nerves there is one in each lateral line, called **lateral nerve.**

The lateral nerves are connected with dorsal and ventral nerves by some **transverse connectives.**

7.12. Reproductive System—Sexes are separate.

A. Male genital organs. These are—

(i) one testis.
(ii) one vas deferens,
(iii) one seminal vesicle,
(iv) one ejaculatory duct,
(v) penial sacs containing penial setae (spicules).

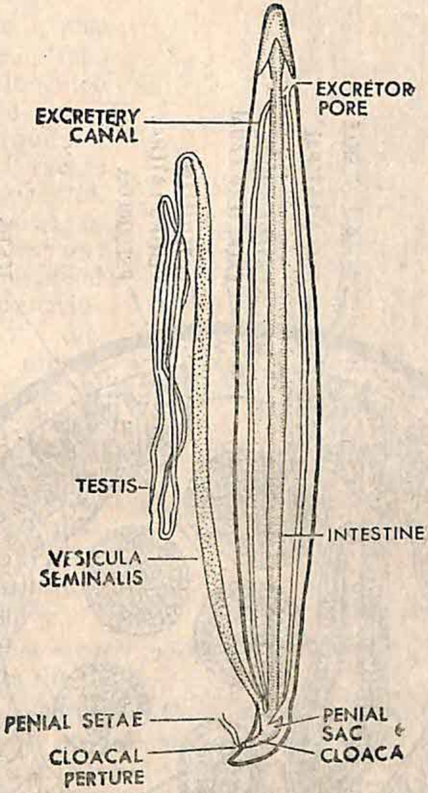


Fig. 7.7. Male genital organs

Testis is a small coiled thread-like structure having an anterior end made up of solid sex cells, middle part with rachis to which sperms are attached. Sperms differentiate at the posterior part of the testis.

Posterior part of the testis is continued as **vas deferens** which becomes wider to form **seminal vesicle** in which sperms are stored before copulation. The seminal vesicle opens through a short duct called **ejaculatory duct** into cloaca.

On the dorsal side of cloaca open two **penial** sacs containing two chitinous **penial setae** attached to the wall of the sac by protractor and retractor muscles. These muscles help this setae to come in or to go out of the sacs. These setae help to stretch the female genital opening during copulation.

Sperms are produced in testis which are round and tailless.

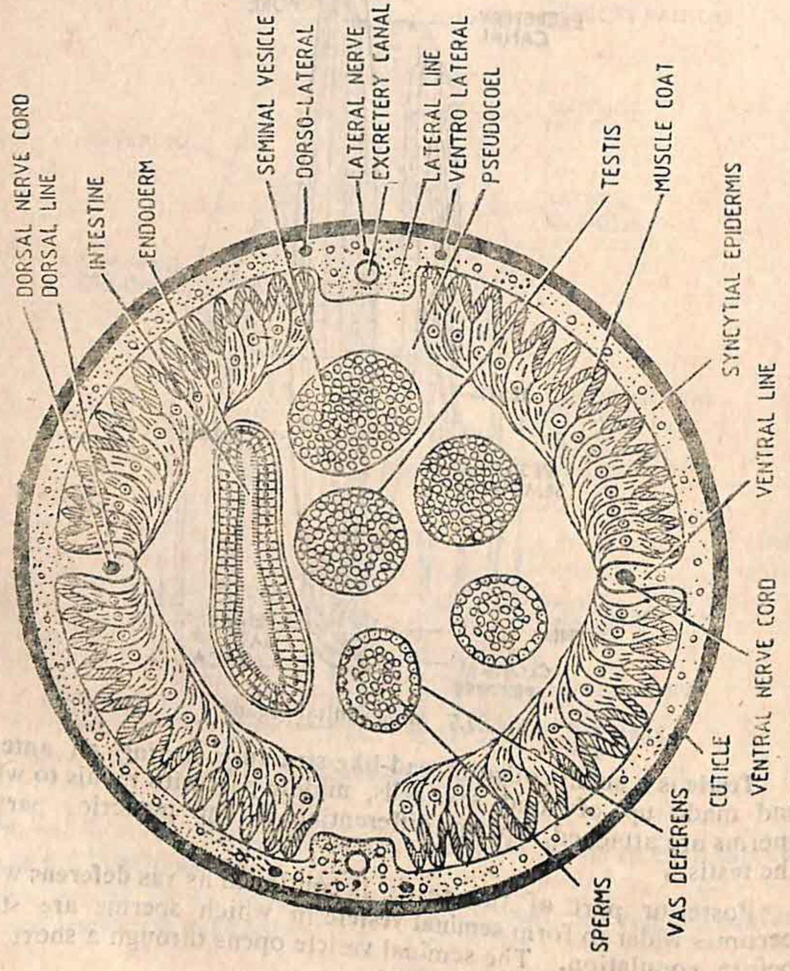


Fig. 7.8. T. S. of male *Ascaris* passing through the middle of the boby

B. Female Genital Organs

These include—

(i) a pair of ovaries,
(ii) a pair of oviducts,
(iii) a pair of uteri,
(iv) vagina,
(v) female genital pore (gonopore or vulva).

Ovaries are also thread-like like testis and are coiled elongated structures. These produce oogonia around a central axis called rachis at their posterior end. From posterior side of each ovary comes out a broader tube called **oviduct**. The posterior expanded part of the oviduct is called **uterus**. The two uteri join to form one **vagina** which opens to the outside by **female genital pore** (gonopore) or **vulva**, lying on mid-ventral side about one-third of the length of body posterior to anterior end.

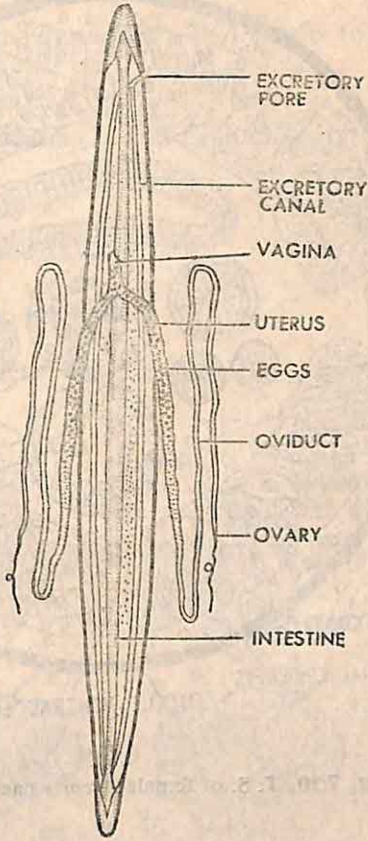


Fig. 7.9. Female genital organs

7.13. **Life-cycle**—*Ascaris* is **monogenetic** i.e., it requires only one host to complete its life-cycle.

(i) **Copulation and fertilization**—*Ascaris* copulate in the intestine of man. During this process sperms are ejected by male into vagina of the female. These move in the uterus when fertilization occurs. While moving further the eggs become covered by a chitinous shell and an outer irregular **albuminous coat.**

The eggs are round or oval (60μ × 45μ), light brown in colour and float in saturated solution of common salt. The unfertilized eggs laid by the mother may mix up with the fertilized eggs but the unfertilized eggs are larger (90μ × 45μ) and sink in saturated salt solution.

Laying of eggs—Eggs laid (20,000-30,000) in the intestine of host come out with faecal matter and undergo segmentation or cleavage.

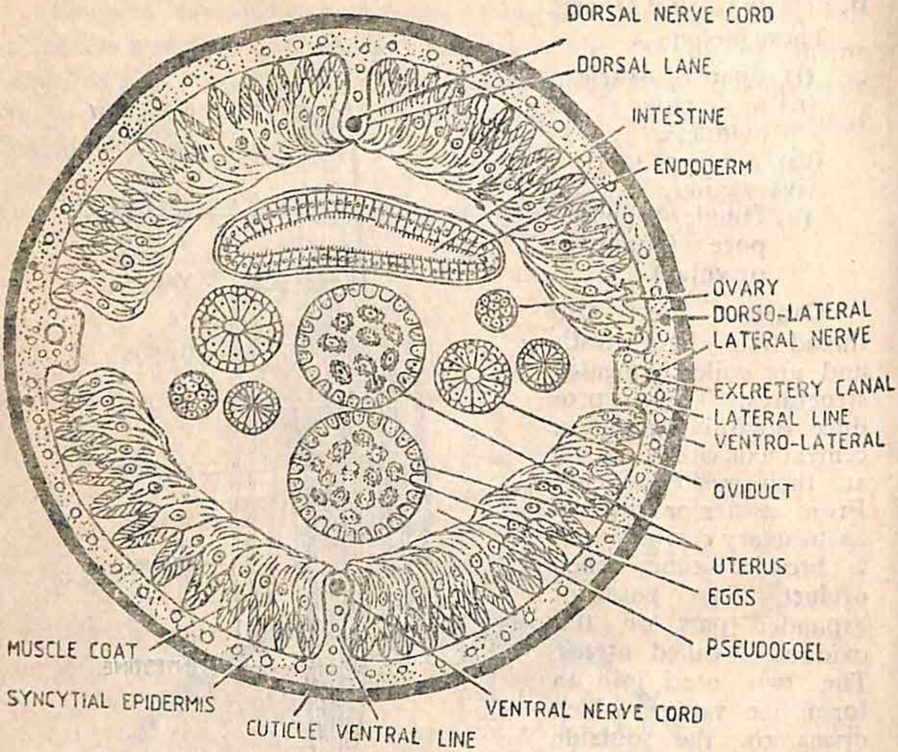


Fig. 7.10. **T. S.** of female *Ascaris* **passing through the middle of the body**

Segmentation (Cleavage)—(i) The spiral and determinate type of segmentation takes place.

(ii) The first **transverse** division forms an upper dorsal (*D*) and a lower ventral (*V*) cell.

(iii) The upper one divides by **vertical** division forming an anterior (*A*) and a posterior (*P*) cell.

(iv) The ventral cell (*V*) now divides transversely to form an upper (*EM*) and a lower cell (V_1).

(v) The embryo is now in the shape of '*T*'.

(vi) Lower cell (V_1) moves towards right as a result (*EM*) comes forward in front of it.

(vii) (*A*) and (*P*) divide to form ectoderm of embryo.

(viii) *EM* divides to form (*E*) and (*M*), (V_1) divides to form V_2 and *C*.

(ix) *E* divides to form **endoderm** (E_1 and E_2) and (*M*) forms the mesoderm.

(x) V_2 divides to form V_3 and *D* cells.

(xi) *C* and *D* divide to form **ectoderm**.

(xii) V_3 by division forms germ cells (G_1 and G_2).

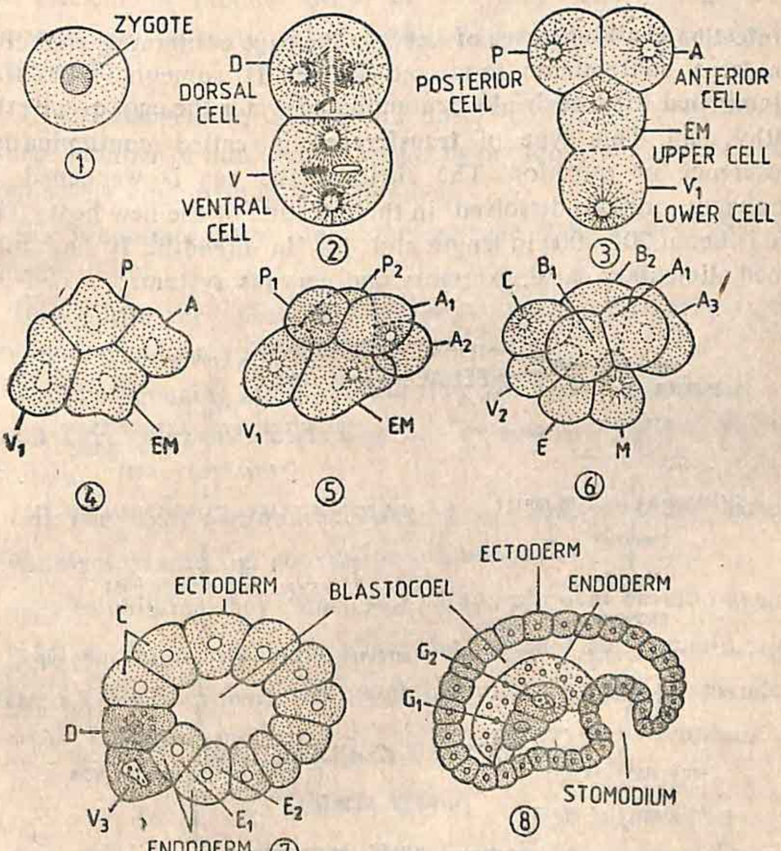


Fig. 7.11. Segmentation of zygote in *Ascaris*

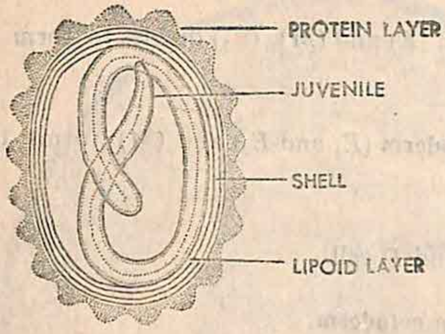


Fig. 7.12. Rhabditiform larva

Thus a **blastula** is formed which changes into **first stage larva** (rhabditoid stage) under favourable condition of temperature (21°-30°C) within the egg.

After a week first moulting takes place within the egg and the first stage larva is changed to second stage larva called **rhabditiform larva** which is the infective stage of *Ascaris*

Infection and Emergence of Larva—The eggs containing rhabditiform larva contaminate food and water. If someone takes this contaminated food or drinks contaminated water the eggs reach the healthy man. This type of **transference** is called contaminative transference or infection. The shell of the egg is weakened in oesophagus and is dissolved in the intestine of the new host. The larva is about 200-300µ in length and 14µ in breadth. It has fully formed alimentary canal, excretory and nervous system.

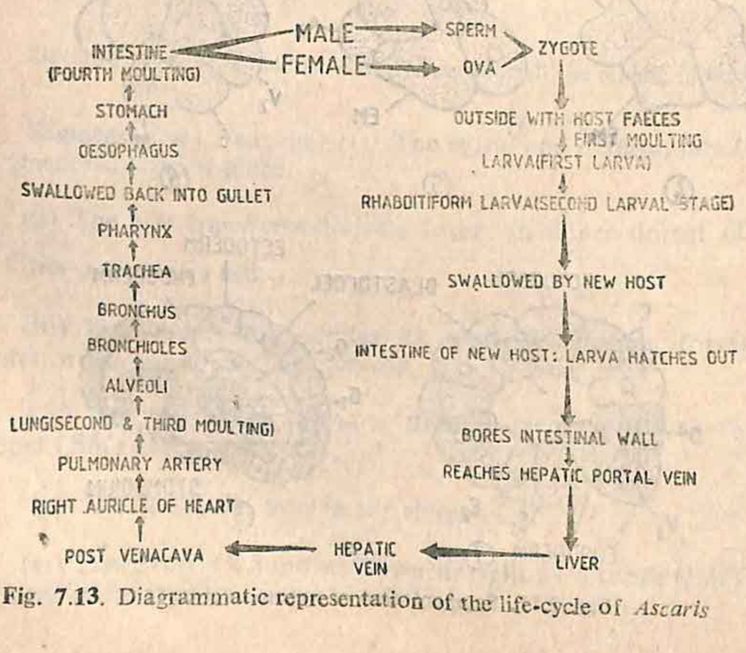


Fig. 7.13. Diagrammatic representation of the life-cycle of *Ascaris*

Migration of Larva—The larva burrows the mucous membrane of the intestine of the host and through hepatic portal vein reaches the liver. From here through portal vein and post-caval reaches the right auricle of the heart. From here through pulmonary arteries reaches lungs. In lungs it moults twice. The first moulting takes place after 5-6 days (third stage larva) and second moulting after 10 days forming fourth stage larva. This larva now increases in size and is about 2 mm in length.

Second Migration—From lung the larva reaches bronchi. trachea, larynx and finally to pharynx where it irritates causing coughing by which it re-enters the alimentary canal. After reaching the intestine it moults fourth or last time. The young *Ascaris* becomes adult sexually mature within 6-10 weeks and begins its life-cycle again.

7.14. **Pathogenicity** (Effect on host)—(i) Due to the presence of a large number of adult roundworms in the intestine the host suffers from severe colic pain in the abdomen.

(ii) Sometimes they block the passage and surgery is the only remedy.

(iii) When they enter the bile ducts and pancreatic ducts, they cause disturbances in digestion.

(iv) By damaging intestinal wall they give rise to **peritonitis.**

(v) They effect on protein digestion by destroying trypsin by their secretion.

(vi) The toxic substances secreted by *Ascaris* cause general nervousness, vomitting, convulsions, diarrhoea etc.

(vii) In children they retard mental and physical development.

(viii) In lungs the larvae cause haemorrhage and sometimes the patient suffers from fever and cough lending to **Ascaris pneumonia.**

WUCHERERIA BANCROFTI

(Filaria Worm)

7.15. The **filaria** worm, ***Wuchereria bancrofti*** **is an endoparasite of the lymph glands, connective tissues of organs, subcutaneous**

tissue, mesenteries and lymph vessels. It produces inflammatory reactions leading to fever, tissue swelling, lymphatic blockage and sometimes grotesque deformities of the limbs etc. called **elephantiasis.** The filaria worm is a digenetic parasite, man is the definitive host and the female mosquito of the genus *Culex* specially *C. pipiens* and occasionally species of *Anopheles* and *Aedes* serves as the transmitting intermediate host or vector.

Filaria worm is widely distributed in tropical Asia, coastal Africa, S. E. North America, China and parts of Japan specially in areas with high humidity.

7.16. The systematic position of *Wuchereria* is—

Phylum—Aschelminthes

Class—Nematoda

Sub-class—Phasmidia

Order—Spiruroidea (Filaroidea)

Family—Filariidae

The parasite gained importance after **Manson's** findings in 1878 that a mosquito acts as the transmitting agent for this parasite. **Manson** (1887) studied the life-cycle of the parasite and suggested reasons for the marked diurnal periodicity exhibited by filaria in the peripheral human circulation. **Vogel** (1928) and **Fain** (1951) gave accounts of the adult structure. The importance of this parasite to mankind is underlined by the fact that four international meets were held in late 1960's to discuss the epidemiology, pathology and control of this worm.

7.17. **Structure**—Filaria exists as adult in the lymph glands and lymph ducts of human being. They are creamy white, filiform and cylindrical lying in complicated coils. The sexes are separate.

Female worms are 65-100 mm long and 0·25 mm in girth. Males are smaller, 40 mm in length and 0·1 mm in diameter. The anterior end of the body tapers to a fine head slightly swollen at the tip which bears the mouth. Mouth is a simple opening devoid of lips. It leads into an oesophagus which is partly muscular and partly glandular. The **tail** in male is curved and has two unequal **spicules** and a number of **papillae.** The female possesses a **vulva** disposed anteriorly and provided with an ovijector. The male and female worms copulate and fertilization like other nematodes is internal.

Development of the fertillized eggs occurs within the mother. The gravid worm gives birth to a large number of small first larva called **microfilaria**. They are shed in the blood and lymph of the host.

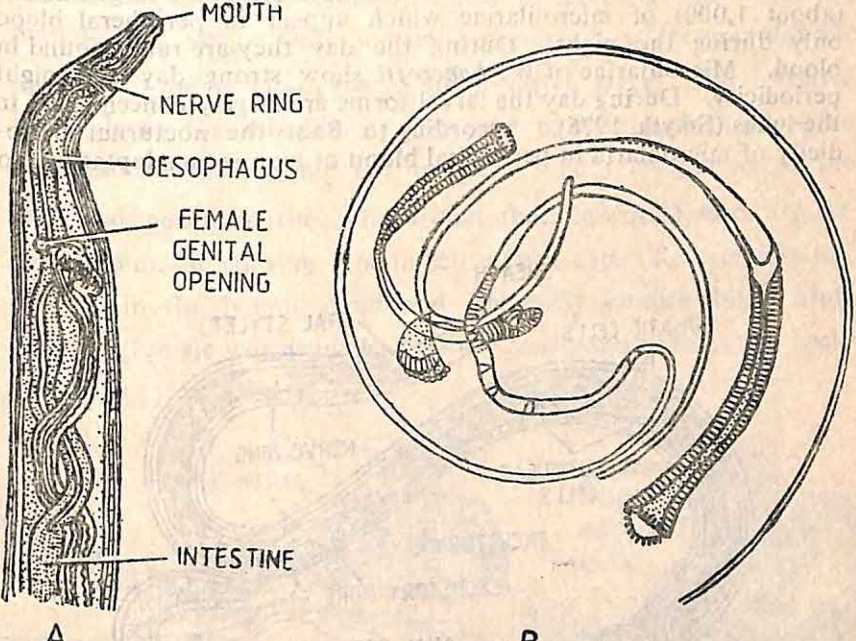


Fig. 7.14. A—Anterior end of ♀; B—Posterior end of ♂ showing spicules and coiled tail

7.18. **Microfilaria**—The live microfilariae are colourless, transparent elongated larvae enclosed in a thin **sheath** which projects prominently beyond both the ends of the larva. The microfilariae of *W. bancrofti* are 225 to 300 mμ long and 10 mμ in diameter. The thin sheath stains red with Giemsa stain. The cuticle of microfilaria is thin and striated and is secreted by a single layer of subcuticular cells. The anterior end is blunt bearing a distinct **cephalic space** and rudiments of adult **buccal cavity** with **oral stylet**. The posterior end is pointed. The body contains nuclei of cells which are used as definite landmarks in the identification of the species to which the microfilaria belongs. A **nerve ring** is seen near the anterior end, behind which at some distance is the **excretory pore** with the rennette or **excretory cell** situated a little behind. The body column is provided with **somatic cells** which are interrupte only by the aforesaid landmarks and a series of usually 4 large celld —the genital rudiment. Near the posterior end is the **anal spot**. Thes tail is devoid of nuclei.

7.19. Life-cycle—The female worm gives birth to a large number (about 1,000) of microfilariae which appear in peripheral blood only during the night. During the day they are rarely found in blood. Microfilariae of *W. bancrofti* show strong day and night periodicity. During day the larval forms are largely concentrated in the lungs (**Smyth**, 1976). According to Bahr the nocturnal periodicity of microfilaria in peripheral blood of man is an adaptation to maintain a tryst with the night biting species of mosquito. The nocturnal periodicity may be related to the diurnal variations in the activity of the host. Further development in the microfilaria occurs only when they are ingested by a female mosquito. On ingestion by the rectorial host, the sheath is lost and the microfilaria migrate rapidly aided by the stylet to the mass of thoracic muscles of the mosquito via the stomach. In these muscles rapid changes take place in the microfilariae. They lie lengthwise in the muscles and shorten to half their original length. They grow more thick and soon change into a sausage-shaped larva. The digestive canal develops and other structures also differentiate.

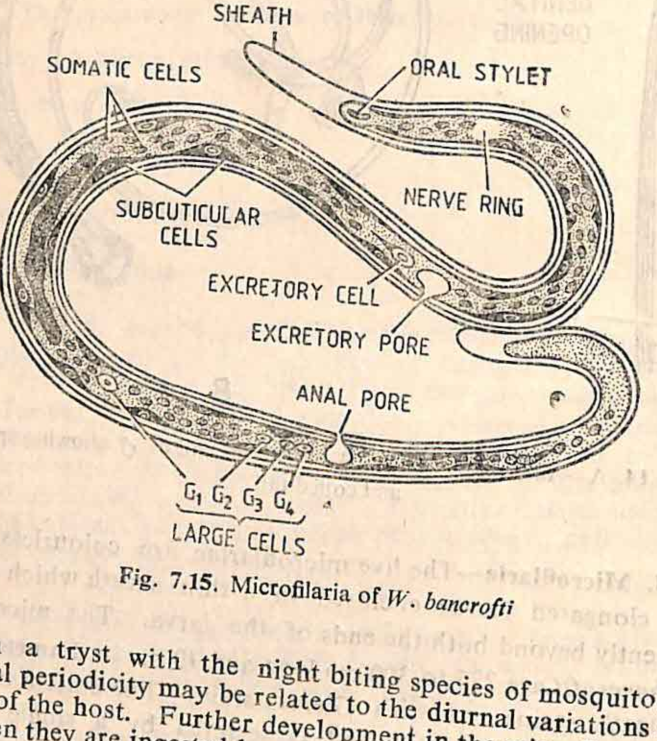


Fig. 7.15. Microfilaria of *W. bancrofti*

The sausage-shaped larva measures 1·5-2·0 mm in length and 20-30 mμ in diameter. As these changes take place the larva moults twice and becomes infective. The formation of the infective stage takes about 10-14 days and occurs best at 27-28°C and a relative humidity of 90%. Only a small proportion of the microfilariae ingested by the mosquito reach the infective stage. The infective larvae leave the thoracic muscles and pass into the head of the mosquito and finally into the proboscis. They escape on to the skin and penetrate the skin through the bite wound made by the mosquito on human skin. The infective larva enters the lymph vessel, coil up in the lymph gland and gradually mature into adult male and female worms in about nine months and restart the cycle (See fig. 7.17. Page 284).

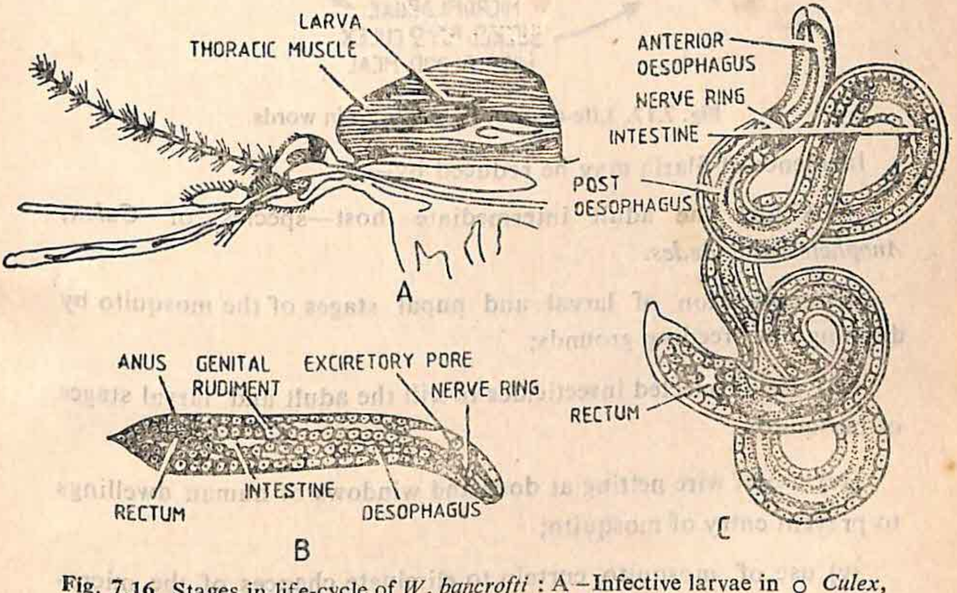


Fig. 7.16. Stages in life-cycle of *W. bancrofti* : A—Infective larvae in ♀ *Culex*, B—Sausage-shaped larva, C—Infective larva

7.20. Control of Filaria—The disease caused by *W. bancrofti* is called **filariasis** characterised by onset of fever, headache and depression. Later when lymphatic passage are severely blocked by the adult and microfilariae **elephantiasis** results.

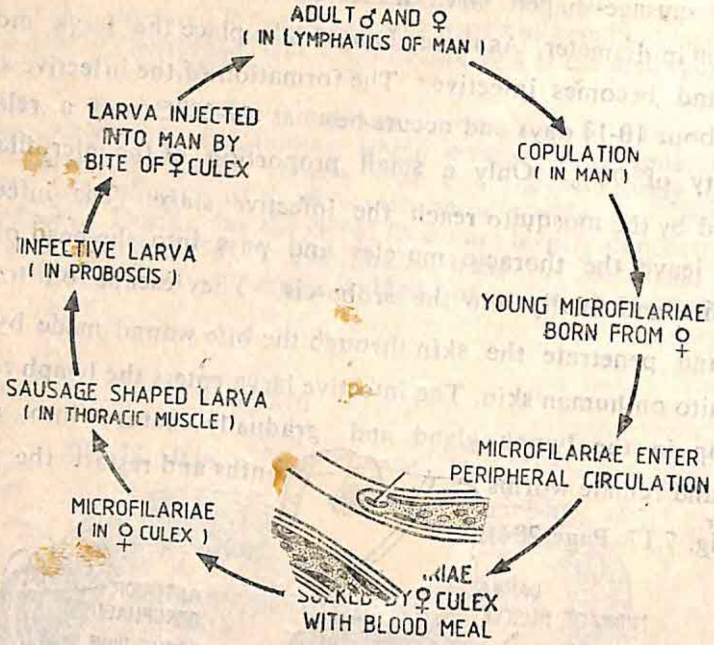


Fig. 7.17. Life-cycle of *W. bancrofti* in words

Incidence of filaria may be reduced by—

(i) killing the adult intermediate host—species of *Culex*, *Anopheles* and *Aedes*.

(ii) eradication of larval and pupal stages of the mosquito by draining out breeding grounds;

(iii) use of selected insecticides to kill the adult and larval stages of mosquito;

(iv) use of wire netting at door and windows of human dwellings to prevent entry of mosquito;

(v) use of mosquito curtain to eliminate chances of the microfilariae reaching the mosquito host.

Dissanaike (1969) has reported that application of control measures have considerably reduced the incidence of filaria in Sri Lanka.

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